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Research Article

Investigations on microbiologically influenced corrosion

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Abstract

Microbial influenced corrosion is a type of corrosion that happen on a metal's surface under the seawater. Microbial influenced corrosion occurs due to the colonization of microorganism on the surface, these microorganisms may be fungus, bacteria or algae. In this project the *E. coli* bacteria are used to investigate the microbial influenced corrosion on metal sample. Metal sample which is an alloy steel is coated with different coatings namely: rubber, epoxy, polyurethane and chrome. Rubber and chrome were spray painted, while epoxy and polyurethane were applied using brush. The samples with these coatings are tested using different tests to find out the best one which can resist microbial influenced corrosion better than the others. These tests are; wet and dry test, atmospheric test, corrosion monitoring test and hardness test. To find the corrosion progress the weight loss and corrosion rate is found in the samples. The optical microscope is used to understand the corrosion progress in the metal surfaces and for the hardness test. The result analyzed shown that polyurethane is the best coating because of its excellent properties in resisting and preventing microbial influenced corrosion.

Keywords: Metals, Alloy steel, Microbial Influenced Corrosion, Polyurethane, *E. coli*.

Introduction

MIC (Microbial Influenced Corrosion) corrosion is a natural process that makes the metals week and lead to its deterioration [1]). It would do the gradual destruction of metal by chemical reaction with their environment and the organism present [2]. Microbiologically influenced corrosion is also called microbial corrosion. It is caused by microbial activities on metal surface. This type of corrosion is mostly known to happen in seawater because the sea environment has a lot of factors that can inspire the organism such as oxygen and chlorine [3,4]. To avoid the MIC a study is carried out by applying different coating with different tests.

MIC corrosion occurs depending mainly on the chloride content, the temperature and the pH value. Chloride content expressed as ppm (parts per million = 0.0001%), some of it values are [5]:

- In freshwater: 0 – 200 PPM (0 – 0.02% by weight).
- In brackish water: Normally up to 15,000 PPM (1.5% by weight).
- In seawater: Normally 15,000 – 36,000 PPM (1.5 – 3.6 % by weight).

The colonization of the microbe makes a layer of biofilm which can become totally corrosive and the corrosion will accelerate. In anaerobic conditions where oxygen presents some bacteria become active and start to grow which will lead to MIC [6].

Materials and methods

The experimental procedure adopted, relevant materials and equipment employed during the investigation are reported here [7,8]. The major steps in the preprocessing are given below:

- The metal sample cut out into 25 pieces.
- Sand-paper (with 100, 120, 180 number) used for blasting the metals.
- Samples are weighed before coating and after coating by using a digital analytical balance with surface hardness test.
- After blasting, the samples are coated with different coatings (4 samples by rubber, 4 samples by chrome, 4 by polyurethane, 4 by epoxy and 4 without coating for comparing).

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- Comparison test between seawater with and without bacteria also was carried out.

The media, which is used as nutrient source was prepared using required grams for 1000 ml of seawater. Substitute into the following equation.

$$\left(\frac{M}{V}\right)_{for\ 100\ ml} - \left(\frac{M}{V}\right)_{for\ 1000\ ml} \dots\dots\dots\dots\dots (1)$$

$$M_{for\ 100\ ml} = 3\ gm \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

Thus 3 gm of TSB weighted using the balance as, then it's added to 100 ml of distillate water. Media was mixed and kept in the incubator for 24 hours at 35Cº. Then original *E. coli* bacteria were used for growing a new generation of the bacteria, as shown in figure 1.

Figure 1. Preparing a new generation of the bacteria

A flame is used to sterilize the loop used to take part of the bacteria. After sterilization the loop it enters slowly to the bacteria tube and a small part of the original bacteria is taken. Then the bacteria were put by drawing on the media that already prepared specially for bacterial growth. The tubes which have drawn bacteria put in the incubator for 24 hrs at 35ºC for growing new generation of bacteria as shown in figure 2.

Figure 2. Prepared media and bacteria in the incubator

Results and discussions

The results of hardness test, wet and dry test and comparison test between seawater with and without bacteria are presented here.

Hardness roughness test

The Rockwell hardness values of different coatings are listed below and shown in figure 3.

Table 1. Value of hardness test

Type of coating	Hardness (HRC)
Epoxy	67.3 RH
Rubber	61.3 RH
Polyurethane	68 RH
Chrome	67.2 RH
Uncoated	108.4 RH

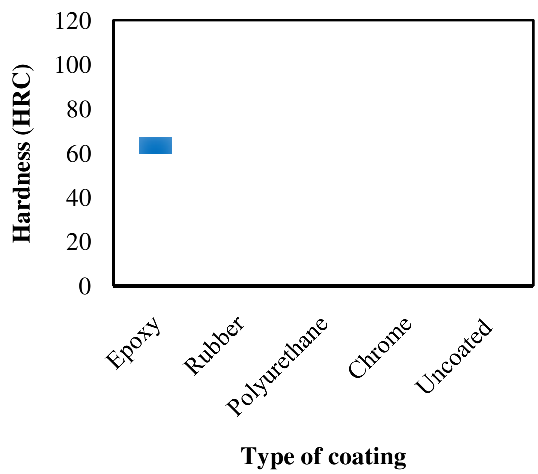

Figure 3. Hardness for samples

Comparison test between seawater with and without bacteria

The samples were tested in 1liter of filtered sea water, which is done in two pool's, one with bacteria and the second without bacteria. The samples were monitored every day. Total period of exposure was for 12 weeks. Corrosion started on different coatings and they are shown in table 2 and figure 4.

Wet and dry test

The coated samples put in sea water for 16 hrs and then dried under sunlight for 8 hrs. The wet and dry test results on different coatings are shown in figure 5.

Table 2. Comparison test for monitoring corrosion

Coated Samples	Exposure Period (Weeks) 2	3	4	5	6	7	8	9	10	11	12
Epoxy		x	x	x	x	x	x	x	x	x	x
Chrome		x	x	x	x	x	x	x	x	x	x
Rubber	x	x	x	x	x	x	x	x	x	x	x
Polyurethane		x	x	x	x	x	x	x	x	x	x
Uncoated	**x**	x	x	x	x	x	x	x	x	x	x

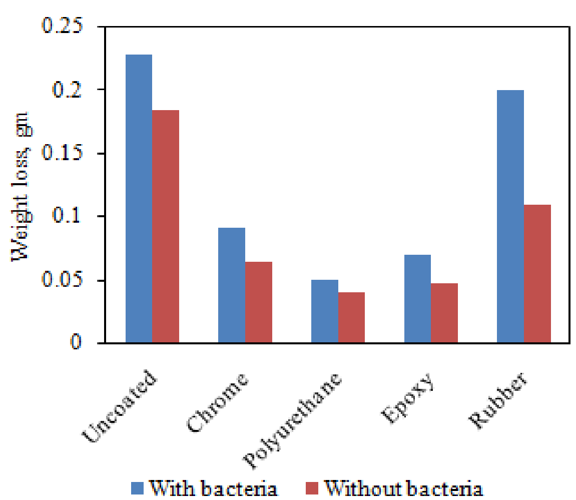

Figure 4. Weight loss of different coatings in comparison test

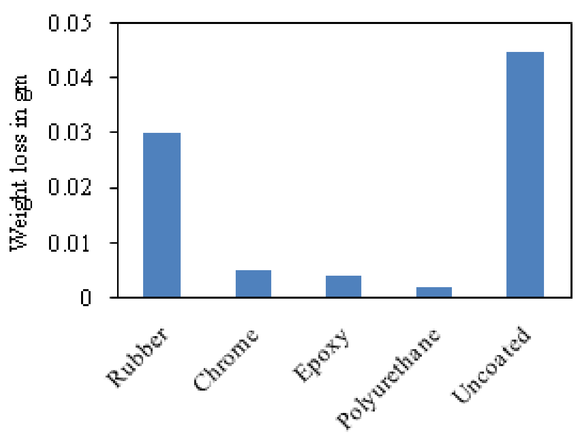

Figure 5. Weight loss in wet and dry test

Microstructure of the corroded samples

The microstructure of coated samples was examined optical microscopes to determine the coating structure. Corrosion formed on the coated samples varies from uniform corrosion and pitting corrosion. The optical structures are presented in figure 6 to figure 13.

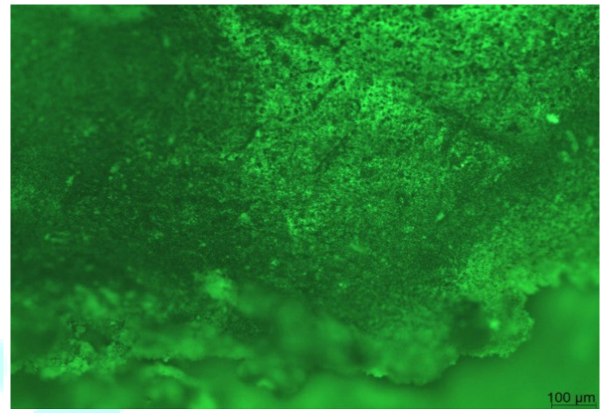

Figure 6. Optical microstructure (100X) of rubber coated sample of seawater without bacteria test

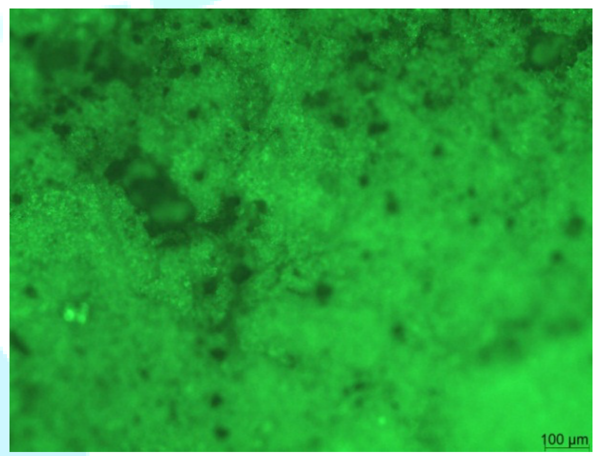

Figure 7. Optical microstructure (100X) of epoxy coated sample of seawater without bacteria test

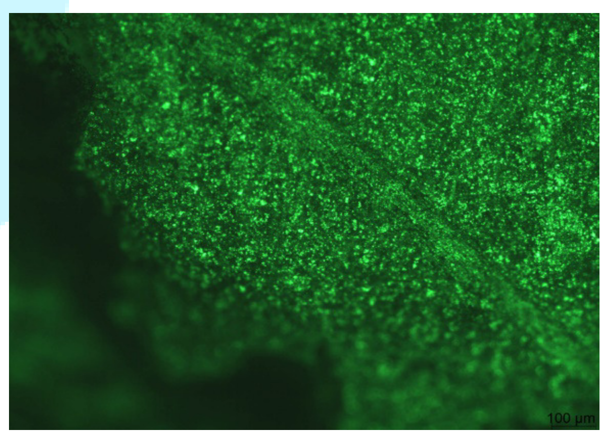

Figure 8. Optical microstructure (100X) of chrome coated sample of seawater without bacteria test

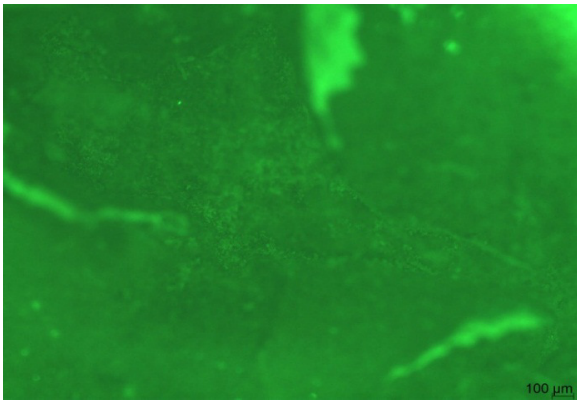

Figure 9. Optical microstructure (100X) of polyurethane coated sample of seawater without bacteria test

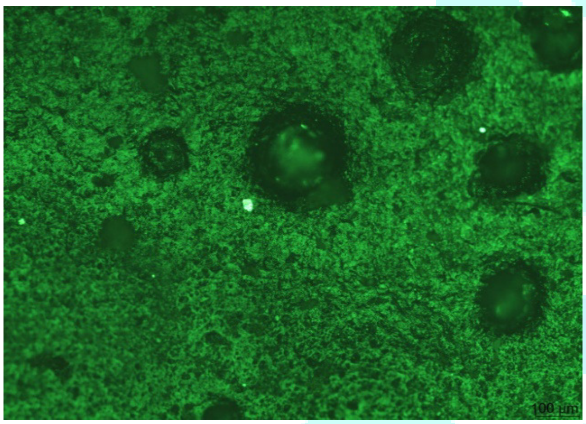

Figure 10. Optical microstructure (100X) of rubber coated sample of seawater with bacteria test

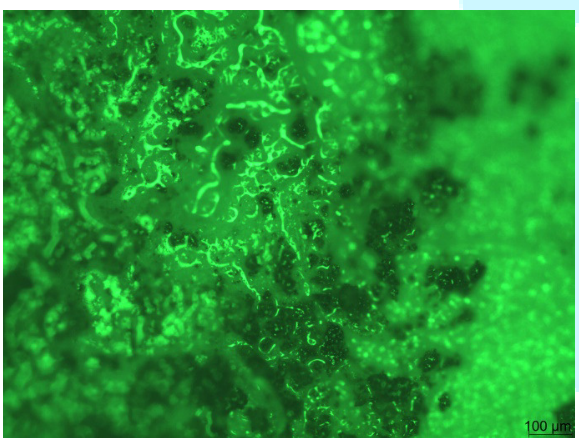

Figure 11. Optical microstructure (100X) of epoxy coated sample of seawater with bacteria test

Polyurethane is found to be the best coating from the test results because of its excellent properties in terms of corrosion resistance. It has good resistance to MIC corrosion because of its good adhesion to the surface. As Shiwei William said in his research about polyurethane coating technology for corrosion protection that "polyurethane have outstanding adhesion values, abrasion and impact resistance, can withstand the damage from another object, excellent chemical and flexibility" [9].

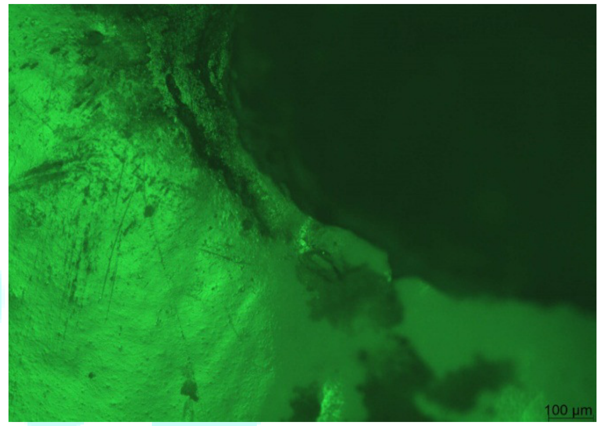

Figure12. Optical microstructure (100X) of polyurethane coated sample of seawater with bacteria test

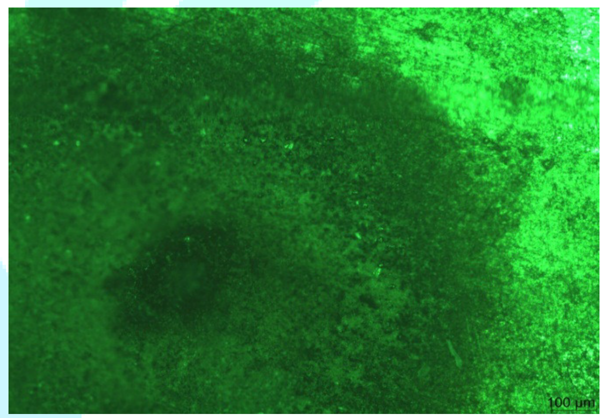

Figure 13. Optical microstructure (100X) of chrome coated sample of seawater with bacteria test

Polyurethane used in this project was a paint, that's what made it stronger because it consists of additive, solvent, resin and pigment. Polyurethane has internal and external uses. Amir Samimi in his research, he proved that polyurethane good also for internal coating in sewage pipeline and it found that no problem occurs during the operation [10]. On the other hand, chrome and epoxy coating also showed a low weight loss, so it can be considered as a good coating. Chrome and epoxy can be developed. In the future the test will be carried out in the microbiological lab with a present of microbiological instruments which help in getting the quantity of the bacteria. Alocit coating can be used because of the properties under seawater is good and useful

Conclusion

MIC corrosion causes lot problems, especially for the pipes under the seawater where the environment condition suitable for colonization of microorganism. The problem can affect the production and lead to economic loss. The MIC corrosion on metal sample and the coating characteristics is investigated. To overcome the problem of microorganism, alloy steel samples from the pipeline under the sea was investigated using *E. coli* bacteria. Different coatings are applied to the samples to find the best suitable one for corrosion resistance. The corrosion rate and coating properties are studied and reported. Among different coatings the best one which can resist the MIC corrosion was found to be polyurethane. Polyurethane has a lot of good properties that help to enhance the corrosion resistance. Chrome and epoxy could also be considered as a good coating with higher layer thickness or mixing them with other material without changing their properties.

Conflict of Interest

Authors declare there are no conflicts of interest.

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