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Study and Investigation of Mic (Microbial Influenced Corrosion) behavior on Stainless Steel with and without Coating

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Abstract: MIC (Microbial Influenced Corrosion) is a type of corrosion that happened on a metal's surface under the seawater, MIC occurs due to the colonization of microorganisms on the surface, these micro-organisms may be fungus, bacteria, or algae. In this project, the E. Coli bacteria are used to investigate the MIC on stainless steel. Stainless steel is coated with a different coating such as rubber, graphene, locate, and epoxy. The samples with different coatings are tested to find out the best one which can resist MIC better than the others. There are different tests carried out; wet and dry test, and atmospheric test. To find the corrosion progress the weight loss and corrosion rate is found in the samples. The hardness of the coating is done to find the best one. The optical microscope is used to understand the corrosion progress on the metal surfaces.

Keywords: Metal, Stainless steel, MIC, alocit, rubber, epoxy, and graphene, E. Coli.

I. INTRODUCTION

MIC (microbial influenced corrosion) corrosion is a natural process that makes the metals week and lead to its deterioration. It also the gradual destruction of metal by chemical reaction with their environment and the organism present. 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. To avoid the MIC a study is carried out by applying different coating with different tests.

Figure 1: Mode of sample preparation before and after

II. PROBLEM DESCRIPTION

Corrosion is the main problem that faces the pipes, structures and machines which lead to deterioration and minimize the life time. To avoid this problem different methods and research have been carried out. This study focused on the MIC corrosion and how to avoid by applying suitable coating.

III. OBJECTIVE

- To study about microbial influenced corrosion of metals.
- To identify suitable type of protective coating for the stainless steel used in a real environment.
- Protective coating like rubber, graphene, alocite and epoxy.
- To optimize the coating and parameters. Parameters are weight loss and corrosion rate.

IV. LITERATURE REVIEW

The following paper describes microbiologically influenced corrosion is one of the well-known corrosions which is occurring because the presence of microorganism activity. This type of microorganism considered one of the main reasons for biofilm formation 5L X52 steel pipeline effects by microbial corrosion investigated in this paper by sulphate reducing bacteria consortium. In this study the SRB consortium was collected from a sour oil well in Louisiana, USA [1]. Methodology and materials used in the study: microorganism and testing medium by using Bar's medium that prepared using (2g) from magnesium sulfate, (5g) sodium citrate, (1g) calcium sulfate dehydrate, (1g) ammonium chloride, (25g) sodium chloride, (0.5) dipotassium hydrogen orthophosphate, (3.5g) sodium lactate 60% syrup and (1g) yeast extract composed. The medium pH adjusted to 7.5 and sterilized for 20 min at 125 C. Then SRB culture and incubated at 37 C for 72 h under nitrogen head space oxygen free. Sulfate reducing consortium identifications by extracting genomic DNA from the bacteria consortium, examine and classified. Pipeline steel coupons prepared, polished and ultrasonically decreased in acetone. After that is sterilized with ethanol for 24h. [2]. As it shows in the results 16S rRNA sequence, gene analysis the mixed bacterial consortium contains three phylotypes: members of firmicutes, proteobacteria and Bacteroidetes. Characterization of the pits and biofilms, which developed over time, is done by field emission scanning electron microscopy (FESEM). In addition, there are other methods utilized in analyzing the corrosion behavior like: linear polarization resistance (LPR), electrochemical impedance spectroscopy (EIS) and open circuit potential (OCP) [3]. EIP results through circuit modeling were used to explain the psych electric interactions between the biofilm, electrode and solution interfaces. The localized extensive corrosion activity of SRB as the results assured is because of the biofilm formed in conjunction with a porous layer of iron sulfide on the metal surface. X-ray diffraction (XRD) detected semi conductive corrosion products mainly consist of a mixture of iron (III) oxyhydroxide (FeO_2H) , iron sulfide (Fe_xS_y) and siderite ($FeCO_3$)which are components in corrosion products that exposed to the SRB consortium.[4]

V. METHODOLOGY

The project methodology all about choosing the best coating to resist MIC corrosion, in the procedures the methodology described by details step by step, it shows the different tests that carryout and the differentiation between the metals in sea water without (E. coli) bacteria and the metals in sea water with bacteria. The metals will be monitored and the result will record and analyzed. The project proposed to utilize the skills and knowledge that gained from my specialization which is process operation and maintenance engineering, to develop something that the industries and society can benefit. After a lot of thinking proposed idea was about microbial influenced corrosion (MIC). Once the proposed idea accepted different literature reviews that mainly focused on microbial corrosion, the information about MIC corrosion on how MIC is handled, what is MIC, its risks and methods applied to prevent. Then metal samples from the real-life pipes line that used under sea water collected a prepared. Different coating applied to the metal and different tests were carried out to find which coating is suitable to resist the MIC corrosion. A list of materials required for the experiment.

VI. PROCEDURE

1. The metal sample cut out into 20 pieces.

2. The specimens are cleaned by using hot water and acid for removing unwanted dust on the surface.

3. Sandpaper (with 100, 120, 180 number) used for blasting the metal samples.

4. After the blasting the samples are coated by different coatings (4 samples by rubber, 4 samples by alocit, 4 by graphene, 4 by epoxy and 4 without coating for comparing).

5. The samples distributed for each test 5 samples for differentiation.

6. Comparison between the metals in seawater without bacteria (E. coli) and metals in seawater with bacteria (E. coli).

7. First test wet and dry test, then atmospheric test and the last test is hardness test.

8. After the coating the sampled weighted then placed in the test to be started.

9. The metals are monitored every day to see the corrosion progress and recorded to analyze the result.

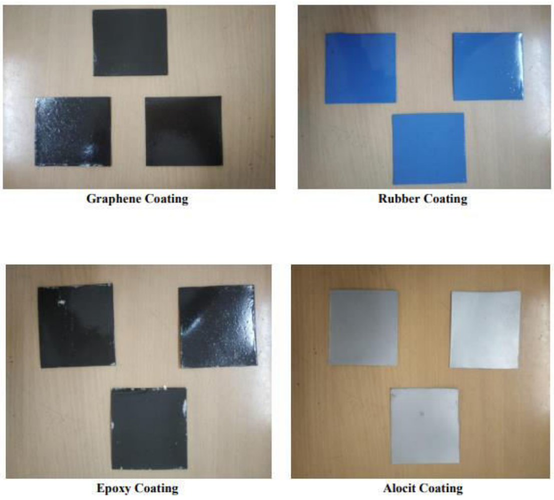

Figure 2: Samples of different coated SS metals

VII. EXPERIMENTAL PROCEDURE

For meeting the project objective certain procedure is followed, which is illustrated in the figure

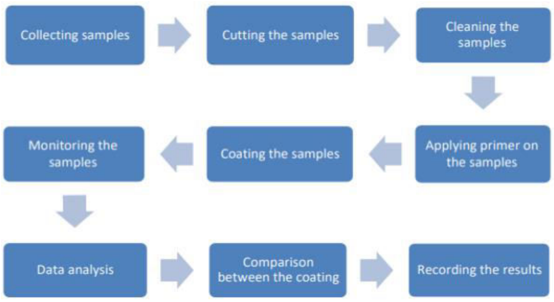

Figure 3: Flow chart

VIII. ROCKWELL HARDNESS TEST PROCEDURE

The Rockwell hardness test was done for the different type of coating. The test is done to measure whether the coating is strong or not and can be determined a cracked happen in the coating or not. The Rockwell hardness test is an indentation test. The indenter used is a conical diamond shape. The optical microscope is used to determine whether there is a crack or not. The test done by setting the indenter on the sample. Then put the scale (3), dewell (3) and limit (10, 199). After that press on the sample by the indenter which controlled by a wheel and measurement will be displayed on the screen.

IX. CALCULATIONS

- Weight loss calculated by Initial weight - Final weight = Weight loss -> (1)
- For calculating the corrosion rate, which based on metal weight loss the followed formulas can be used:

CR (mm /y) = w/(a*A*T)-> (2)

Where:

-W is weight loss

-a is metal density = $7.87*10^{-3}$ g/mm^3

-A is the metal surface area = 5806.44mm^2

-T is the time of exposure in year = 0.0986years (36 days)

X. RESULTS AND DISCUSSION

Graphene is the best coating as the result shows because of its excellent properties. It has good resistance to MIC corrosion because it adhesion. As of graphene coating technology for corrosion protection that "graphene have outstanding adhesion values, abrasion and impact resistance, can withstand the damage from another object, excellent chemical and flexibility" The graphene weight loss was hard to get because it absorbs water which makes difficult to get the weight loss of the metals without letting them dry under sunlight for 8 hours. The hardness test result shows the good flexibility of the polymeric coating were no crack occurs. The coating act as barrier layer to protect the samples. Coating performance is influenced by thickness, composition, continuity, resistance to microbial degradation and adhesion to the metal substratum.

Table 1: Corrosion rate for comparison test, substitute in equation (2)

Corrosion rate	Samples without bacteria (mm/y)	Samples with bacteria (mm/y)
Epoxy coating	$0.06/7.87*10^{-3}*5806.44*0.0986$ = **0.0133**	$0.09/7.87*10^{-3}*5806.44*0.0986$ = **0.0199**
Rubber coating	$0.10/7.87*10^{-3}*5806.44*0.0986$ = **0.0221**	$0.19/7.87*10^{-3}*5806.44*0.0986$ = **0.0421**
Graphene coating	$0.02/7.87*10^{-3}*5806.44*0.0986$ = **0.0044**	$0.03/7.87*10^{-3}*5806.44*0.0986$ = **0.0066**
Alocit coating	$0.07/7.87*10^{-3}*5806.44*0.0986$ = **0.0155**	$0.12/7.87*10^{-3}*5806.44*0.0986$ = **0.0266**
Uncoated	$0.15/7.87*10^{-3}*5806.44*0.0986$ = **0.0332**	$0.22/7.87*10^{-3}*5806.44*0.0986$ = **0.0488**

Table 2: Values of hardness test Without Bacteria

Type of coating (Without Bacteria)	Hardness (kgf)
Epoxy	26.1
Rubber	29.8
Graphene	40.3
Alocit	30.4
Uncoated	62.4

Table 3: Values of hardness test With Bacteria

Type of coating (With Bacteria)	Hardness (kgf)
Epoxy	23.4
Rubber	24.2
Graphene	39.1
Alocit	28.6
Uncoated	59.7

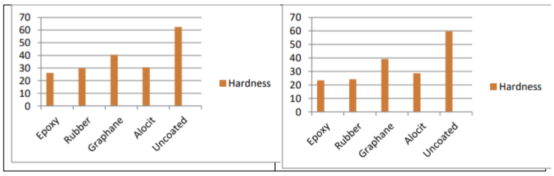

Figure 3: Hardness of the samples without and with Bacteria

For Samples without bacteria corrosion rate of epoxy coating is 0.013, rubber coating is 0.0221, grapheme coating is 0.0044, alocit is o.o155 and uncoated sample is 0.0332. for samples with bacteria the corrosion rate of epoxy coating is 0.0199, rubber coating is 0.0421, grapheme coating is 0.0066, alocit is 0.0266 and uncoated sample is 0.0488. After comparing the samples by applying coating, the samples which get least value of corrosion rate is said to be best one for the mic corrosion of stainless steel and that is graphene coating. In all tests grapheme coating is reported as best coating among all four coatings.

XI. CONCLUSION

MIC corrosion causes lots 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 objective for this project is reached. The MIC corrosion on metal sample and the coating characteristics is investigated. To overcome the problem of microorganism real life sample this is alloy steel samples from the pipeline under the sea investigated in this project by using E. coli bacteria. An e. coli bacterium is enhanced by oxygen and the colonization of the bacteria increased. The new generation of the bacteria helped in increasing the corrosion rate, media which the food for the bacteria is essential for bacteria to live. Different coating is applied to the samples to find the suitable one for corrosion resistance. The corrosion rate and coating properties are studied and reported. Among different coating the best one which can resist the MIC corrosion was graphene. Though rubber and epoxy also considered as a good coating by developing them multi layers of coating. Graphene is the best coating as the result shows because of its excellent properties. i.e., Resistance to Water, Tear Resistance, High Load Bearing Capacity etc., It has good resistance to MIC corrosion because its adhesion and stability with the MIC and other colonization of microorganism in sea water.

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