Influence of Surface Roughness and Paint Coating on Corrosion Rate

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The technology of paint and its application develop fast, driven by the increasing cost of energy, raw material and labors. In this study, paint was used as a corrosion inhibitor on the surface of API 5L while saltwater is used as the corrosive media. The coating was varied for three different cases, i.e. primary coating only, primary and color coating as well as primary, color and glossy coating. Meanwhile, surface roughness was varied for 0.6, 0.7 and 0.8 μm. It is concluded that surface roughness and coating influence the corrosion rate. Smoother the surface and more coating layers lower the corrosion rate. Based on the study on API 5L steel, the lowest corrosion rate was obtained at 0.6 μm with 3 paint coatings (primary, color paint and clear/gloss).

Keywords: *API 5L steel; surface roughness; corrosion rate; paint coating*

1. INTRODUCTION

The technology of paint and how to use it develop rapidly, driven by the increasing cost of energy, raw material and workers. Unfortunately, not all coating technologies deliver a good quality product. One of the factors is the surface roughness which can determine the quality of the coating quality. The smoother the surface, the better the painting quality [1,2]. Many industries and construction businesses use metal alloy since metal alloy has good quality and has combined characteristics from its composers. An exemplary metal that often used underwater by the offshore oil company is API 5L. This type of steel is considered as low carbon steel with 0.28 wt% carbon concentration [3]. In this study, paint was used as a corrosion inhibitor on the surface of API 5L while saltwater acts as the corrosive media. The results were expected to inhibit corrosion on API 5L with varied surface roughness. The result thus can be applied in the industry so that the corrosion management can be optimized.

Surface roughness is an important parameter in the manufacturing process. Arifin *et al.* [4] reported that surface roughness is influenced by the rolling process, depth of cut and feeding rate during of milling process. In agreement, Rahardjo *et al.* [5] reported also that the depth of cut and feeding rate of the CNC machine also influences the surface roughness.

2. METHODOLOGY

In this work, surface roughness was varied at 0.6, 0.7 and 0.8 μm. The specimen dimension is shown in **Figure 1**. The surface of the specimens was cleaned and smoothed using sandpaper with 500, 1000 and 1500 grit. Then, the surface roughness was measured using surface tester until the surface roughness of the specimen achieved 0.6 μm, 0.7 μm and 0.8 μm. After that, the coating was performed with 3 varied conditions,i.e.1 paint coating (primary paint only), 2 paint coatings (primary and color paint) and 3 paint coatings (primary, color, and clear/gloss paint). The paint thickness of each coating was measured with the coating thickness tester. The paint thickness was considered the same for all specimens, i.e. thickness of 1 paint layer was 40 - 50 μm, thickness of 2 coat layers was 90 - 100 μmand thickness of 3 paint layers equals to 140 - 150 microns. The initial weight before immersion (W1) was noted. Each sample was then immersed in 3.5% NaCl for 288 hours. After being immersed for this duration, specimen weight (W2) was measured by using the digital scale with the accuracy level up to 0.0001 gr. The corrosion rate was obtained from the calculation using a weight loss formula (eq. 1) [4,5]. The corrosion rate can be classified into some criteria like in **Table 1**.
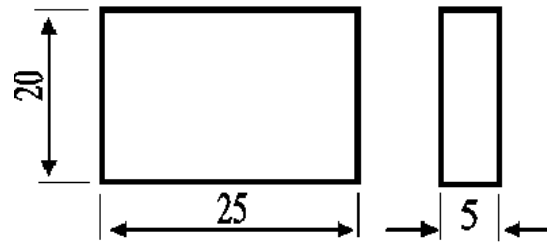
Figure 1. The specimen dimension (all units are mm)

$$CR = \frac{K \times W}{A \times t \times D} \tag{1}$$

Where,

CR	= corrosion rate [mpy]
K	= constant of corrosion rate $= 3.45 \times 10^6$ [mpy/mmpy]
W	= weight loss [g]
A	= surface area of specimen [cm^2]
t	= immersion duration [hours]
D	= specimen density [g/cm^3]

Table 1. Classification of corrosion resistance based on corrosion rate

Relative corrosion resistance	mpy	mm/yr	μm/yr	nm/hr	pm/sec
Outstanding	<1	<0,02	<25	<2	<1
Excellent	1-5	0,02-0,1	25-100	2-10	1-5
Good	5-20	0,1-0,5	100-500	10-50	5-20
Fair	20-50	0,5-1	500-1000	50-150	20-50
Poor	50-200	1-5	1000-5000	150-500	50-200
Unacceptable	200+	5+	5000+	500+	200+

3. RESULT AND DISCUSSION

3.1 Influence of surface roughness on the corrosion rate of API 5L steel without any paint coating
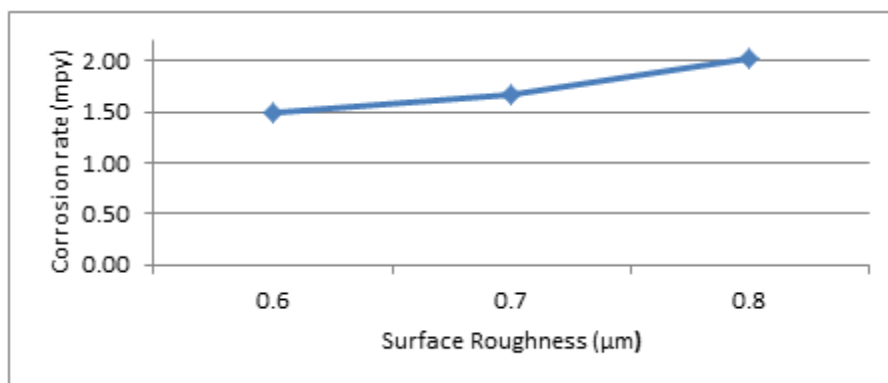

Figure 2. Influence of surface roughness on the corrosion rate of API 5L steel without any paint coating

Without any paint coating, the corrosion rate of API 5L increases with higher surface roughness (**Figure 2**). The corrosion rate of 1.4944 mpy occurred for the surface roughness of 0.6 μm. Meanwhile, the corrosion rate of surface roughness 0.7 and 0.8 μm are 1.6733 and 2.0206 mpy respectively. The rough surface of the metal enables the formation of charge poles which finally become anode and cathode. Smooth and clean surface inhibits corrosion. When the surface roughness of 0.6 μm, the surface is smooth, thus the poles of anode and cathode are less which impedes corrosion reaction. This result is in agreement with the result of many previous studies, i.e. the higher the surface roughness values, the higher the corrosion rate values [6-8].

The surface roughness of the metal will influence the coating quality since the smooth surface will

create a good coating quality. If the surface is rough, the coating will be rough and it triggers the formation of the cathode, anode and thus corrosion reaction [5]. Coating presence impedes corrosion reaction. Non-coated API 5L steel was easy to corrode since the steel surface had direct contact with a saltwater solution. The corrosion rate of API 5L steel without any coating in this circumstance is considered to be sufficiently low and the level of resistance is considered excellent (1-5 mpy).

3.2 Influence of surface roughness on the corrosion rate of API 5L steel with 1 paint coating
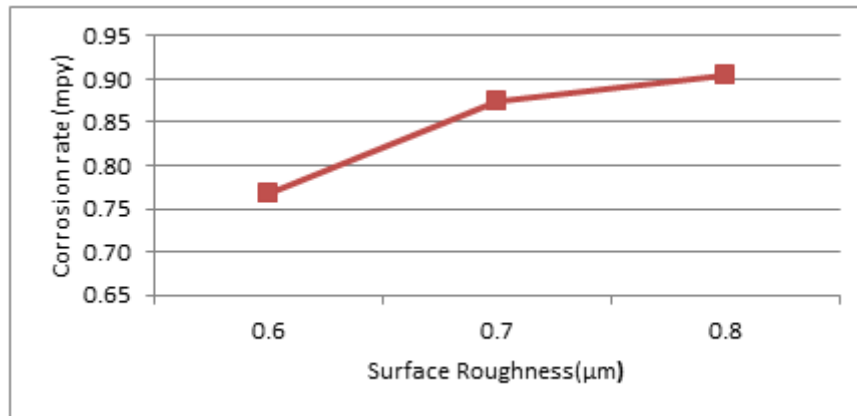

Figure 3. Correlation between surface roughness and corrosion rate on API 5L steel with 1 paint coating

For the first case, the API 5L steel was coated only with paint primary paint. The primary paint was used as the base paint for steel surface and it provided corrosion resistance and sticking ability between steel and the next paint coating. When the API 5L steel was coated 1 paint coating, the corrosion rates for surface roughness of 0.6, 0.7 and 0.8 0.8 μm are 0.77, 0.87 and 0.91 mpy respectively (**Figure 3**). In this case, the corrosion rate is smaller than the corrosion rate of the steel without any coating since the primary coating reacted directly with the saltwater solution which then inhibited the corrosion of steel surface. This primary paint can inhibit corrosion since it contains epoxy resin. Even though the steel has been coated with primer paint, it still can corrode since corrosion cannot be prevented, it can only be inhibited[9].

   The corrosion rate increase as the surface roughness increases since surface roughness influences coating quality. As surface roughness increases, the coating quality became worse and the structure of the paint surface follows the surface roughness. Based on Table 1, the corrosion rate of API 5L steel for the first case is thus considered low and the corrosion resistance is considered outstanding (<1 mpy).

3.3 Influence of surface roughness on the corrosion rate of API 5L steel with 2 paint coatings
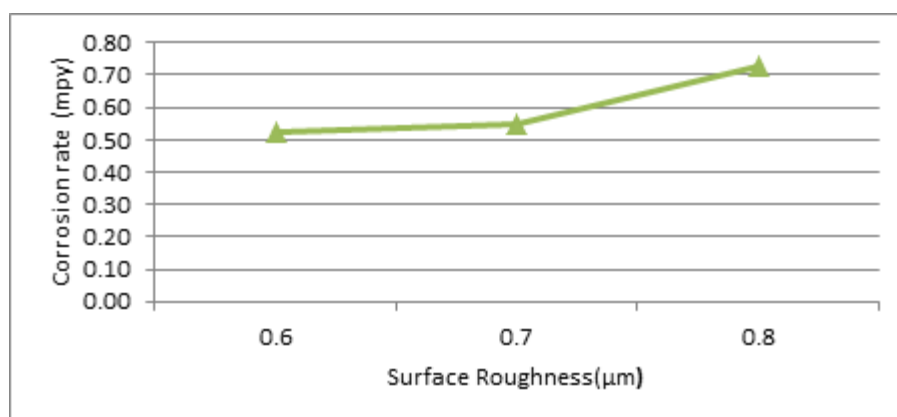

Figure 4. Correlation between surface roughness and corrosion rate on API 5L steel with 2 paint coatings

For the second case, the API 5L was coated with 2 paint coatings, i.e. primary and color paint. Primary paint was used to increase corrosion resistance and adhesiveness between steel and the next pain coating. The second coating is aimed to provide color to the steel. The corrosion rates for the surface roughness of 0.6, 0.7 and 0.8 μm are 0.53, 0.55 and 0.73 mpy respectively (**Figure 4**). The corrosion rate for the surface roughness of 0.6 μm is smaller than at the surface roughness value of 0.8 μm. The higher the surface roughness, the higher the corrosion rate is. The corrosion rate of steel with 2 coatings(the second case) is lower than that of the first case

(primary paint only) since the paint in the first case can be peeled off from steel surface which results in direct contact between saltwater and steel surface without any protection from the primary paint. Meanwhile, primary paint is protected by the color paint for the second case. In the second case, NaCl has more contact with the color paint and less contact with the primary paint. This leads to better protection for steel. The corrosion of API 5L steel with 2 paint coatings is considered low and the resistance level to corrosion is considered outstanding (<1 mpy).

3.4 Influence of surface roughness on the corrosion rate of API 5L steel with 3 paint coatings
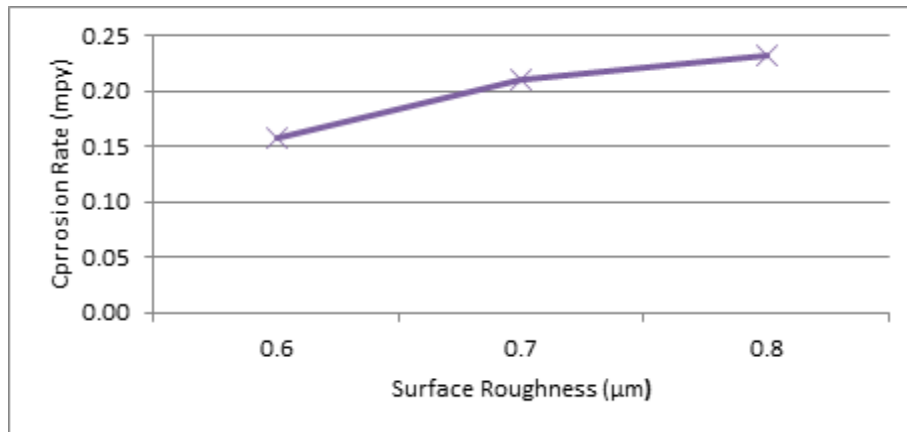

Figure 5. Correlation between surface roughness and corrosion rate on API 5L steel with 3 paint coatings

In the third case, steel is coated with 3 paint coatings, i.e. primary, color, and glossy coating. Clear (glossy) coating as the final varnish in 2 coating system painting was aimed to provide a glossy outlook and anti-scratch protection for the paint. Similar to the first two cases in this study, the corrosion rate increases as the surface roughness increases. The corrosion rate for surface roughness of 0.6, 0.7 and 0.8 μm are 0.1579, 0.2105 and 0.2315 mpy respectively.

When API 5L steel was coated with 3 paint coatings, the corrosion rate is considered low and resistance level is outstanding (<1 mpy). The corrosion value is very low compared to the corrosion rate of the steel without paint coating, 1 paint coating and 2 paint coatings. Thus, 3 coating layers at the steel surface can inhibit the corrosion more excellently since steel with 3 coatings has a thicker protection layer which prevents the corrosion so that the solution is difficult to initiate any corrosion [10,11]. On 3 paint coating, the corrosion rate is the lowest among the other coatings since it has the thickest coating comprising of 3 coating layers (primary, color paint and clear/gloss) so that the salt solution becomes more difficult to initiate any corrosion on the steel surface. Moreover, gloss paint contains silicon which further inhibits corrosion. Even though the steel has been coated with 3 coatings, it is still possible to corrode since corrosion cannot be prevented, but managed. Additionally, paint coating has very small pores that can be passed by atmospheric air and solution which generate any corrosion.

4. CONCLUSION

Based on the result, it can be concluded that surface roughness and coating influence strongly the corrosion rate. The smoother the surface and the more the coatings, the lower the corrosion rate is. The corrosion rate on steel without any coating is the highest since the steel does not have any protection from the corrosive environment. The corrosion rate for the first case is lower than the steel without any coating since the steel is protected by the primary coating, i.e. epoxy coating which provides steel protection from corrosion and higher adhesiveness between the steel and the next paint coating. On the steel with 2 paint coatings, the corrosion rate is lower than the steel with 1 coating since the steel is protected by color paint which has direct contact with a corrosive environment. The steel with 3 paint coatings (primary, color paint and clear/gloss) has the lowest corrosion rate since the last coating contains silicon which provides additional protection from corrosion. Even though the steel has been coated with 3 coatings, it is still possible to corrode since corrosion cannot be prevented, but can only be managed. Moreover, paint coating has very small pores that can be passed through by the air and the solution which causes corrosion.

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