Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2018, 5(6):249-253**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Inhibition of Metal Stainless Steel 304 Corrosion using Arabic Gum Inhibitor on Phosphate Acid Solution (H_3PO_4)

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Abstract Corrosion is the degradation of the metallic material properties caused by the reaction between the metal and its environment producing the metal oxide which will affect the performance of the metal. Usability of stainless steel 304 (SS304) in general as materials of industrial machines and so on, but it turns out SS304 not resistant to acid environment karna can cause corrosion, so need protection. In general by the addition of inhibitors to the environment using chemical inhibitors such as chromate, etc., but this material is toxic and has a negative impact on the environment. To overcome this in this study using green inhibitor arabic gum is environmentally friendly. The effect of arabic gum on metal corrosion resistance in the environment of H_3PO_4 in this study using weight loss method and SEM analysis to see the morphology of metal surface. From the results of the research with the concentration of 3% arabic gum concentration into the environment of 0.1M H_3PO_4 has the greatest inhibitor efficiency of 66.4 % and can decrease the corrosion rate during the first 1 days immersion without inhibitor of $3.35X10^{-5}$ mpy and after using the arabic gum inhibitor to $1.13X10^{-6}$ mpy.

Keywords SS304, Corrosion rate, Green Inhibitor, Arabic gum

1. Introduction

SS304 is a stainless steel having element content: 0.04% C, 0.45% Si, 1.96% Mn, 18.42% Cr, 9.74% Ni, 0.0065% P and 0.011% S, the chromium content present in SS304 steel makes it resistant to corrosion due to the formation of oxide coating on the metal surface. On the other hand steel SS 304 is steel that is cheaper than other SS, and can be applied to various industrial and non industrial fields. Although SS304 has some advantages in terms of hardness, it is easy to clean, but corrosion resistance to conditions in acidic environments is considerably less, which will result in degradation of these metals which will have an impact on the performance degradation of the metal [`].

2. Literature Review

Corrosion is the process of material degradation caused by chemical reactions with the environment [2]. In ordinary language, corrosion is usually known as rust, corrosion or rust generally occurs in iron. Iron is a rusty metal, iron rust is a substance produced in the event of corrosion, ie in the form of solids with a reddish brown color that is fragile and porous. If allowed, over time the iron will run out to rust. In general, this attack can not be prevented, we can only try to control it so that the structure or component has a longer life. To cause a corrosion, there are several component requirements that must be met, such as [1]:

1. The presence of a cathode, a material that undergoes a reduction reaction because it has a more positive potential when measured by a potential calculation. The cathodic reaction to metal corrosion, among others:
   a) Reduction of oxygen (acid) : $O_2 + 4H^+ + 2e \rightarrow 2H_2O$
   b) Oxygen reduction (base) : $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$
   c) Evolution of hydrogen (acid) : $2H^+ + 2e^- \rightarrow H_2$

d) Evolution of hydrogen (base) : $2H_2O + 2e^-$ → H_2+2OH^-
e) Metal Deposition : $M^{2+}+ 2e$ → M
f) Reduction of metal ions : $M^{3+} + e^-$ → M^{2+}

2. An anode, a material undergoing oxidation reaction and loss of material because it has a more negative potential when measured by potential calculation. Anodic reaction to metal corrosion among others:
   a) Metal corrosion : M → $M^{n+}+ne^-$
   b) Oxidation of ferrous ions : Fe^{2+} → $Fe^{3+}+e^-$
   c) Evolution of oxygen : $2H_2O$ → $O_2+4H^++4e^-$

Corrosion is a multilevel damage that occurs in a material due to chemical reactions with its environment. The corrosion process requires several conditions, including anodes, cathodes, electrolyte / media solutions, and electrical circuits, therefore an inhibitor is required to inhibit the corrosion rate of steel SS 304 [3].

To protect SS304 from corrosion can be used by media modification, material selection, cathodic protection, anodic protection, coating and with corrosion inhibitor. So far the use of corrosion inhibitors is one of the most effective ways to prevent corrosion because the cost is relatively cheap and the process is very simple, A corrosion inhibitor is defined as a substance which, when added in small amounts into the environment, will decrease corrosion attack in steel structures. In this study, the inhibitor used is arabic gum, arabic gum is one polysaccharide as a safe inhibitor because it is environmentally friendly and non-toxic [3-4].

The weight loss method is the calculation of the corrosion rate by measuring the severe shortage due to corrosion. This method uses the duration of the study to obtain the amount of corrosion loss that occurs. The calculation of the corrosion rate on the basis of weight loss during the test is in accordance with ASTM G1 standard as in the equation below:

$$CR = \frac{K \times W}{A \times T \times D}$$

Note;
CR = corrosion rate (mpy)
K = constant corrosion rate = 3.45×10^6 (mpy)
W = weight loss (g)
T = immersion time (hour)
A = area sample (cm^2)
D = density metal g/ cm^3

3. Research Methodology

This research uses SS304 metal which has composition 0.42% C, 1.19% Mn, 0.034% P, 0.006% S, 0.049% Si, 18.24% Cr, 8.15% Ni, and the remaining Fe with density 8.00 g / cm^3 cut to 1x1 cm. This research was conducted in the environment of phosphoric acid H_3PO_4 with 0.1 M; 0.3 M and 0.5 M with pH 2 and using 1%, 2% and 3% arabic gum inhibitors, to see the morphology of the metal surface is done by using Scanning Electron Microscope (SEM), TM 3000 model, Hitachi at 500X magnification (Anggraeni. 2008), to know the corrosion rate using weight loss method by metal test immersion in phospohric acid solution (H_3PO_4) with variation of concentration 0.1 M, 0.3M and 0.5M for 1-5 days. The tested metal material is firstly hydrated in order to make the metal surface more homogeneous and the metal surface becomes cleaner by means of mechanical grinding tools and 800 graded sandpaper and 1500 subsequently cleaned using acetone. The provision of a perfect metal surface is essential to produce a homogeneous uptake on the metal surface.

The inhibitor used in this study is a green Arabic gum inhibitor derived from an acacia tree obtained from Sigma chemical (St. Louis, MO). Arabic gum material is weighed as much as 0.5 g before being dissolved using 1000 ml of distilled water. Arabic gum is a polysaccharide that has a polysaccharide chain structure. This polysacharide chain structure is composed of D-galactopiranous (GALP) elements associated with L-Arabofuranose (ARAF), L-Rhamnopyranose (RHAP), and D-Glucuronic acid (GA) [4-6].

4. Results and Discussion

Metals test before corrosion testing is done by weighing the initial weight (W_0), then for corrosion testing is done on the phosphoric acid (H_3PO_4) environment with concentrations of 0.1M, 0.3M and 0.5M without and with the addition of green Arabic gum inhibitor with concentration 1 %, 2%, 3%, where duration of immersion time; 1, 3 and 5 days, after the test sample is finished immersion, the test sample was cleaned again and then dried and re-weighed to know the change of weight (W_1). To observe the morphology of the log surface the SS304 test was performed using a spectroscopy electron microscope (SEM) with 5000x magnification (Wang et al., 2012), where it is very clear that, metals immersion for 1-5 days in 0.1 M H_3PO_4 environment of surface look rough and not homogeneous. This indicates that the metal surface has corrosion when compared to the same conditions but added with the arabic gum inhibitor at a 1% concentration of fine metal surface, while the surface of the metal with the addition of 3% Arabic gum looks more smooth and homogeneous, it shows on the surface does not experience corrosion. In the presence of Arabic gum inhibitors which are terabsopsi on metal surface, this is in accordance with the results of research [5]. For more details SEM analysis results can be seen in Figure 1. (a,b and c)

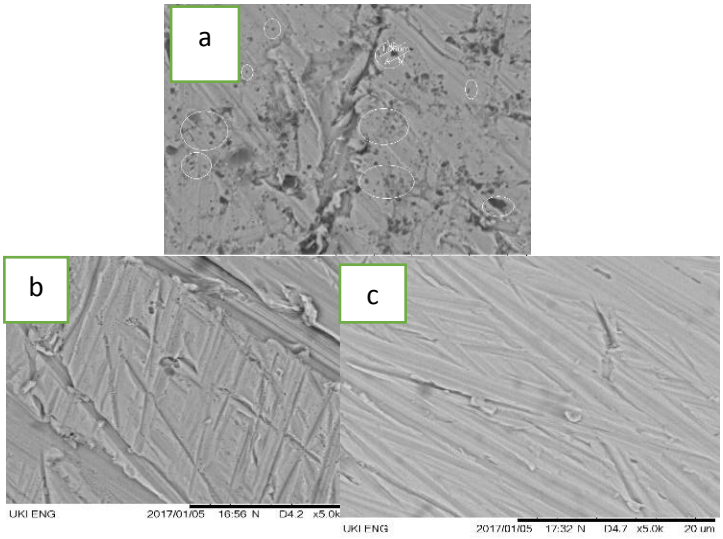

Figure 1: Photo SEM SS304 with 5000x magnification environment 0.1M H_3PO_4 with 1 day immersion time; (a) without addition of an inhibitor; (b) by addition of 1% of the arabic gum inhibitor; (c) with the addition of 3% inhibitor arabic gum

Corrosion testing using weight loss method, for SS304 metal in 0.1 M H_3PO_4, 0.3 M H_3PO_4 and 0.5 M H_3PO_4 environment and with without addition of 1%, 2% and 3% inhibitors with test immersion time of 1.3 and 5 days . The weight loss results for SS304 metal in the environment of 0.1 M H_3PO_4 have lost weight (1 day, 0.1184 g, 3 days, 0.1203 g and 5 days 0.128 g), this shows that in the acid environment SS304 weight loss increases. With the addition of 1% inhibitor to the environment of H_3PO_4 during the test of 1, 3 and 5 days, the weight loss values for (1 day; 0.043 g, 2 days; 0.068 g and 5 days; 0.1249 g) still below the value if without inhibitors, it points to the influence of the absorption of Arabic gum on the surface according to the theory of Dalo et al [5]. Umoren et al [6]. Furthermore it applies also to the addition of inhibitors with 2% concentration, weight loss in (1 day; 0.0533 g, 3 days, 0.0911g and 5 days; 0.1249 g), seen weight loss increasing but still below from metal SS304 without addition of Arabic gum inhibitor. Furthermore, for the addition of 3% of Arabic gum inhibitor to 0.1 M H_3PO_4 environment, we found the weight loss value (1 day; 0.0398 g, 3 days; 0.0716 g and 5 days; 0.0716 g), SS304 weight loss is lower than that of the without inhibitor environment. For a clearer comparison graph the weight loss can be seen in Figures 2a and 2b.

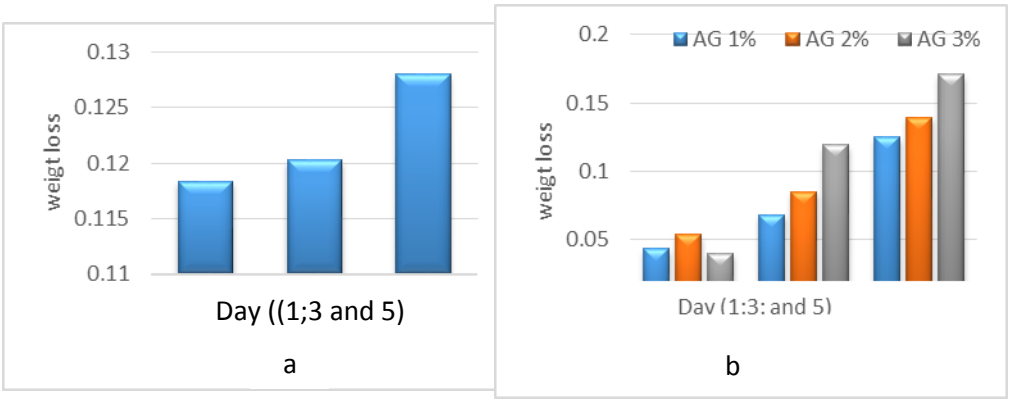

Figure 2: Graphs of heavy weight loss of SS 304 on 0.1 M H_3PO_4 (a) without arabic gum inhibitor) and (b) with addition of 1%, 2%, 3% arabic gum inhibitor with immersion time of 1, 3 and 5 Days

Testing of SS304 metal on 0.3 M H_3PO_4 at immersion 1, 3 and 5 days from weight loss method, SS304 without addition of inhibitor lost weight (1 day, 0.1197 g, 3 days, 0.1212 g and for 5 days; 0.1278 g) weight loss is increasing compared to the environment at 0.1 M H_3PO_4. With the addition of 1% inhibitor to the environment, with the same immersion treatment for 1,3 and 5 days, there was a loss of (1 day, 0.075 g, 3 days, 0.0849 g and 5 days, 0.1196 g) weight loss value below SS304 value without inhibitor. For 2% treatment with the same treatment, weight loss for (1 day 0.0683 g, 3 days, 0.116 g and 5 days, 0.1172 g), weight loss value is lower than the test metal without the addition of an arabic gum inhibitor. Furthermore, with the addition of 3% obtained weight loss results (1 day, 0.0682 g, 3 days, 0.1122 g and 5 days, 0.1216 g), weight loss increased but still below the test metal without inhibitor. For more details can be seen in Figures 3a and 3b.

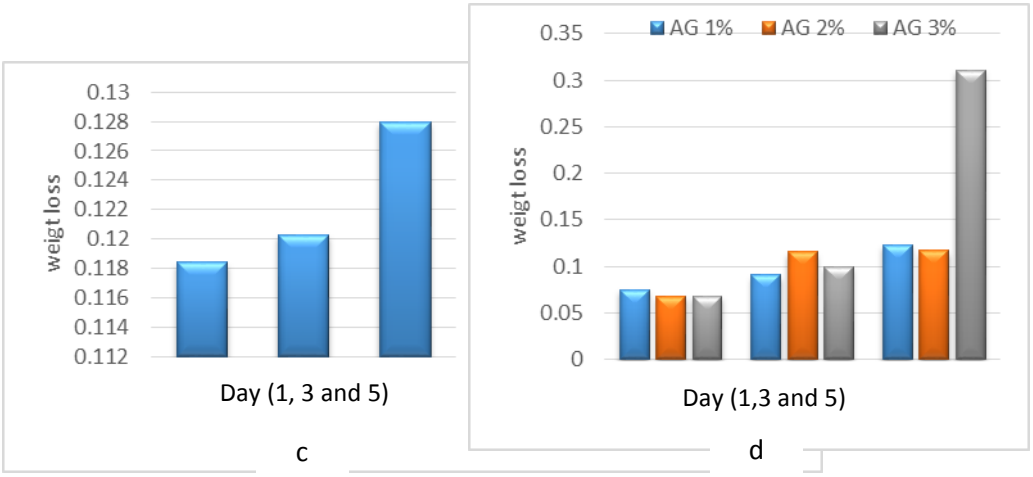

Figure 3: Graph of losing weight of SS 304 on H_3PO_4 0.3 M; c without inhibitor arabic gum and (d) with the addition of 1%, 2%, 3% arabic gum inhibitor with immersion time of 1, 3 and 5 days.

Testing of SS304 metal in the environment of 0.5 M H_3PO_4 with no soaking for 1, 3 and 5 days was obtained by weight loss (1 day, 0.128 g; 3 days; 0.1092 g and 5 days; 0.132 gram) with addition of 1% arabic gum inhibitor losing weight to (1 day; 0.0602 g, 3 days; 0.1193 and 5 days; 0.1193 g) seen decreased weight decreased compared with the environment without inhibitor. With the addition of 2% of arabic gum inhibitors lose weight (1 day; 0.0762 g, 3 days; 0.1000 g, and 5 days; 0.1111g), then with the addition of 3% Arabic gum inhibitor then losing weight for (1 day; 0.0831 g, 3 days; 0.1126 g and 5 days, 0.4170 g). Increasing the value of weight loss even exceeds SS304 metal without inhibitors, this indicates if the acidity concentration increases and the addition of inhibitor arabic gum is higher, then the metal surface will be more damaged. For clearer comparison of weight loss can be seen on graph 4d and 4e.

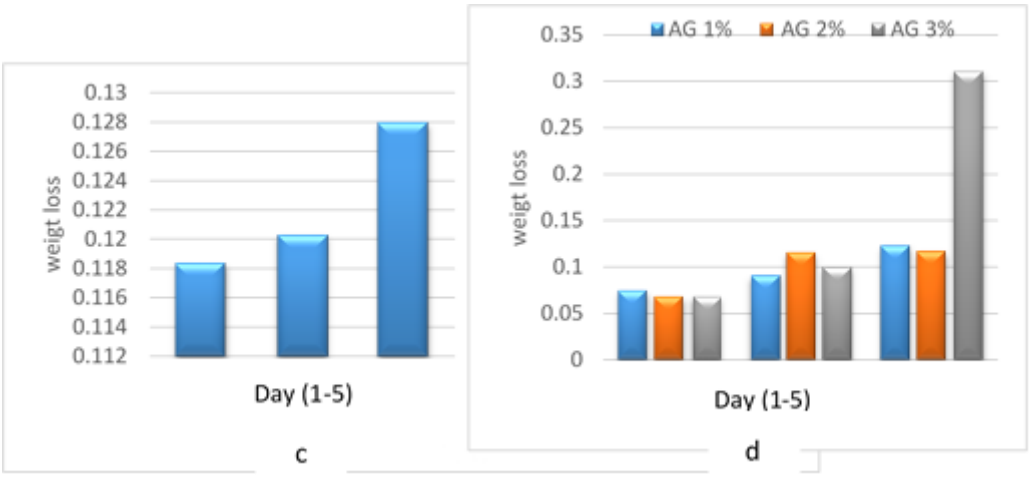

Figure 4: Graph of weight loss SS304 environment on H_3PO_4 0.5 M; (e) without inhibitor arabic gum and (f) with the addition of 1%, 2%, 3% arabic gum inhibitor with immersion time of 1, 3 and 5 days

Corrosion rate analysis through calculation was found that, corrosion rate increased along with increasing H_3PO_4 concentration, the effect of addition of arabic gum inhibitor depends on concentration of arabic gum and H_3PO_4. The highest efficiency is in 0.1M H_3PO_4 environment with 1 day immersion time in addition of 3% Arabic gum inhibitor with 66.4% efficiency with $1.13X10^{-6}$ mpy corrosion rate, which if we compare with SS304 metal condition in same environment but without inhibitor with a higher corrosion rate of $3.35X10^{-5}$ mpy. It can be concluded that Arabic gum can decrease the rate of corrosion in SS304 metal in the environment of H_3PO_4 acid, this is due to the Arabic gum inhibitor which contains polar atoms such as, O, N, P which can be adopted on the metal surface to form a passive layer, so that corrosion resistance is increasingly increased [4].

5. Conclusion

In SS304 study in H_3PO_4 environment with increasing concentration of H_3PO_4 and length of immersion time of weight loss and corrosion rate is increasing, SEM testing with 5000x magnification of metal surface morphology without inhibitor looks more rough than if there is addition of inhibitor surface look more smooth and homogenous. The results showed that the 3% arabic gum absorbed on the surface of metal 304SS in 0.1M H_3PO_4 had the smallest weight loss and corrosion rate and had the greatest inhibitor efficiency compared with 1% and 2% Arabic gum inhibitors. It can be concluded that arabic gum with enough concentration of 3% can be used as an inhibitor on metal SS304 in environment 0.1M H_3PO_4 so it is expected this material can be used more durable to be applied in industry and non industry ...

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