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Steel Corrosion Behaviour in Acidic Solution for Application in Petrochemical Distillation Systems

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Abstract. The electrochemical reaction response of austenitic 316L stainless steel and carbon steel was examined through weight loss analysis in 1M, 2M and 3M of HCl acid. The results show that austenitic 316L has high corrosion resistance than carbon steel for the test analyzed with the lowest corrosion rate of 0.0018mm/y at 1M of HCl and highest at 0.0053mm/y when compared with carbon steel which has the lowest corrosion rate of 0.0003mm/y for 1M of HCl and highest at 0.0013 mm/y of 3M of HCl solution all at ambient temperature conditions. General corrosion was displayed on the surface of the carbon steel but austenitic 316L was not affected due to the presence of chromium alloy and other alloying elements.

1. Introduction

Steels are generally used as metallic structures for equipment in petrochemical industries such as crude distillation, valves, trays, atmospheric distillation overhead column, condenser, desalter units etc. They contain excellent physical and mechanical properties that can make them survive and withstand high rate of corrosion caused by contaminants from crude oil. Contaminants are the major challenge of petrochemical industries and when they are mixed with water corrosion is formed. Corrosion affects every part of the steel structures of the petrochemical industries, some occur at faster rate while others at slow corrosion rate. Huge losses of revenue have been recorded in petrochemical industry as a result of corrosion maintenance [1-5], which ranges from million dollars to billions of dollars spent yearly. Research showed that stainless-steel [6-8] and carbon steel [9-12] are generally used for petrochemical's structural equipment. Carbon steel are considered for use due to its low cost, good toughness, good formability, weldability, low strength, availability, wear resistance, ductility but low corrosion rate. Most petrochemical industries prefer carbon steel for their equipment because of low cost, which can be replaceable from time to time even when they corrode fast. While stainless-steel equipment in petrochemical industries stay longer for years without been speedy affected by corrosion for high life span and ductility. For instance, austenitic stainless steels, possess high ductility, high passive film protection and high corrosion resistance as a result of the presence of chromium and other alloying elements which shows that they are excellent steel material for petrochemical structural equipment. This research focuses on examining the behaviour of electrochemical reaction of austenitic 316L stainless-steel and carbon steel in HCl acids varied concentration for applications in petrochemical distillation units.



2. Material and Methods

2.1. Material

Austenitic 316L stainless-steel and carbon steel were gotten for this research work and analyzed. The steels have a square dimension of 100 and 100mm respectively.

Table 1. Composition of Carbon Steel [13].

Element	C	Si	Mn	V	Nb	Mo	Cr	Cu	Ni	Al	Fe
% Content	0.125	0.52	1.83	0.078	0.053	0.079	0.121	0.296	0.091	0.043	96.2

Table 2. Composition of 316L Stainless Steel [14].

Element	Cr	Ni	Mo	C	Mg	P	S	Si	N	Fe
% Content	16	10	2	0.03	2	0.05	0.03	0.75	0.1	69.05

2.2. Acid solution test

A specific concentration of the dilute HCl acid solution was prepared with distilled water to dilute the grade of HCl (37%) purity for the test corrosive environment used to represent the petrochemical atmospheric distillation overhead system.

2.3. Preparation of the steel samples

The carbon steel and austenitic 316L stainless steels were machined into test for 3 samples of each steels. Carbon steel with diameter of 160mm and the dimension of the square shaped austenitic 316L steel of 100 mm by 100mm were used for the research. Abrasive of silicon carbide was used to prepare the metallography of the two ends surfaces of the two steels, ranging with the papers size of 80, 120, 220, 800 and 1000 grits. The steel samples were polished with diamond liquid, rinsed with acetone, distilled water and dried. They were later stored in the desiccator for weight loss test measurement analysis [15].

2.4. Weight loss analysis

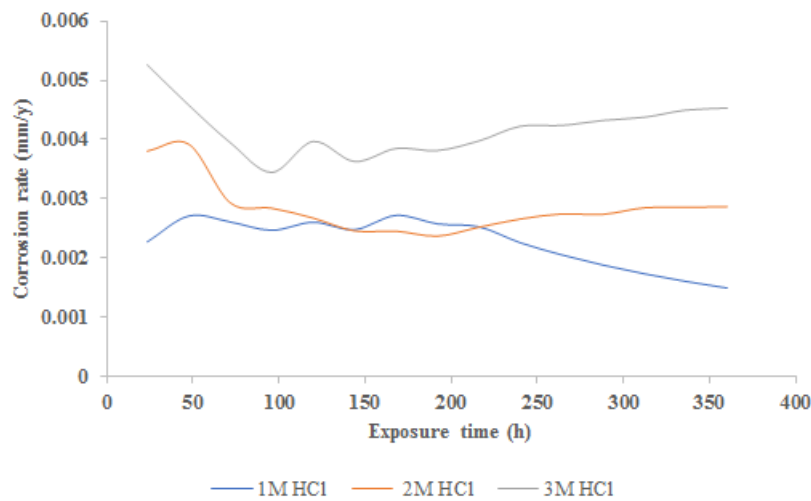
The weight loss experimental setup of the cylindrical shaped carbon steel coupons and square shaped austenitic 316L stainless steel coupons were weighed using a weighing balance. The carbon steel and austenitic 316L stainless steel were both immersed in 200ml of 1M, 2M and 3M of HCl acid. The entire experiment was exposed to the atmosphere and the coupons were fully immersed at ambient temperature for the period of 360 hours. Each sample were analyzed at every 24 hours after washed with distilled water, dried and weighed with the weighing balance [16].

3. Results and Discussion

3.1. Weight loss measurement

The graph obtained from the data of the weight loss measurement for weight loss(w) and corrosion rate (mm/y) for austenitic 316L stainless-steel and carbon steel in HCl acids are displayed in figures (i) and (ii) below reveals the corrosion rate against time in the HCl acid media for the two steels. The reaction of HCL acid on the steel led to a dissolution of metallic anodic reaction causing oxidation to occur by release of electrons at the anode. The reaction proceeded at the cathode by reduction process of release of protons. All these processes led to the corrosion reaction of the steels.

(i)



(ii)

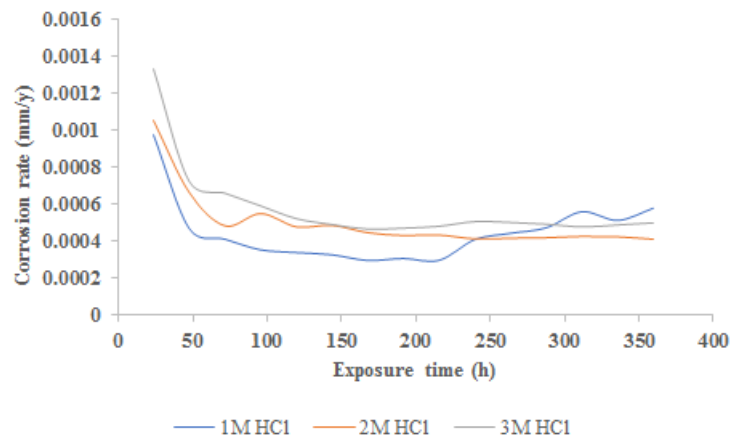


Figure 1. (i) corrosion rate versus exposure time for Austenitic 316L samples in 1M, 2M and 3M HCl acid solution, (ii) is a plot of corrosion rate versus exposure time for carbon steel samples in 1M, 2M and 3M HCl acid solution.

The observation from the graphs showed that the corrosion behaviour of austenitic 316L for the three (3) samples responded differently. The sample with 3M of HCl had the highest corrosion rate all through the exposure time than the other two of 1M and 2M respectively. However, there was reduction in the corrosion rate significantly down the exposure time due to the film protection or passivation on the surface of the austenitic 316L stainless-steel, which slows down the corrosion rate gradually.

The carbon steel performed differently by showing a weak corrosion resistance, which gradually occurred throughout the period of exposure time. The 3M HCl sample of the carbon steel had the highest rate of corrosion, which drastically and practically reduced down the reaction of the exposure time. The carbon steel corrosion resistance strength was obviously lower than austenitic 316L stainless-steel with a great difference. This is due to the presence of chromium formation of the alloy properties of the 316L, showing that 316L stainless steel is highly sustainable for structural applications in petrochemical equipment, especially distillation overhead systems.

4. Conclusion

Austenitic 316L stainless-steel showed far stronger and higher corrosion resistance to general corrosion when compared with carbon steel in 1M, 2M and 3M HCl acid solution due to the presence of the alloy composition (chromium, nickel) of 316L. The percentage corrosion damage was absolutely different which showed that austenitic 316L possesses a high formation of passivation or film protection by the alloying element. As a result of these, austenitic 316L showed excellent perform for stable corrosion resistance behaviour than carbon steel and makes it suitable for general purpose of structural applications in petrochemical distillation overhead units. This helps to save cost and its shows high sustainability for eco-friendly petrochemical distillation systems at a long run.

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