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To cite this article: A O Araoyinbo et al 2018 IOP Conf. Ser. Mater. Sci. Eng. 374 012044

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The Effect of Aggressive Corrosion Mediums on the Microstructure and Properties of Mild Steel

A O Araoyinbo1,*, M A A Mohd Salleh2, A Rahmat2, A I Azmi1, W M F Wan Abd Rahim1, D C Achitei2,3 and T S Jin1

1Faculty of Engineering Technology, Universiti Malaysia Perlis, UniCity Alam, Perlis Malaysia
2Center of Excellence Geopolymer and Green Materials (CEGeoGTech), School of Materials Engineering, Universiti Malaysia Perlis (UniMAP), Perlis, Malaysia
3Gheorghe Asachi Technical University of Iasi, Faculty of Materials Science and Engineering, Blvd. D. Mangeron 41, 700050, Iasi, Romania

Email: alaba@unimap.edu.my

Abstract. Mild steel is known to be one of the major construction materials and have been extensively used in most chemical and material industries due to its interesting properties which can be easily altered to suit various application areas. In this research, mild steel is exposed to different aggressive mediums in order to observe the effect of these interactions on its surface morphology and properties. The mild steel used was cut into dimensions of 7 cm length and width of 3 cm. The aggressive mediums used are 100 mls of aqueous solution of hydrochloric acid, sodium hydroxide (40 g/L), and sodium chloride (35 g/L) at room temperature. The characterizations performed are the hardness test with the Rockwell hardness tester, the surface morphology by optical microscope, surface roughness and the weight loss from the immersion test. It was observed that the hardness value and the weight loss for the different cut samples of mild steel immersed in the different aggressive mediums reduces with prolong exposure and severe pitting form of corrosion was present on its surface.

1. Introduction

Corrosion is a worldwide phenomenon and have been acknowledged by many researchers to be a problem that strongly influences our industrial environments.

Corrosion process is sometimes misunderstood and if not properly identified and characterized at certain times this can result to in service material degradation leading to negative impact on the safety of the environments. In many cases, corrosion has acted as life span limiting factor for both structural and fabricated components [1]. Corrosion and some forms of pollutions can be said to be interrelated as it is known that there is the possibility of harmful processes accelerating a corrosion process [2, 3].

Since rust from metal iron can act as a source of pollutants when it comes in contact with water bodies, both processes have the capability to influence the quality of the environment, and the efficiency of the industries. Therefore, it is essential to be able to apply corrosion engineering knowledge, methods and techniques to reduce the corrosion activity [4].

Corrosion is the deterioration of materials by the chemical interactions with the different environments.
Most metals have the tendency to interact with its environment when it is exposed under certain conditions, this interactions often leads to the formation of metal oxides with visible corrosion products when the passive films layer breaks down due to prolonged exposure and lack of protection [5-8]. Steel materials can be susceptible to attack in aggressive media when exposed to form rust. Since steel find use in a wide area of applications it becomes even more important to avoid any catastrophic failure and huge financial losses when in use [9, 10].

In this study, the corrosion behaviour of mild steel was investigate when exposed to different aggressive mediums.

2. Materials and methods
The raw materials and chemicals used in this project are mild steel which was locally purchased, and three aggressive mediums of aqueous sodium chloride (neutral), sodium hydroxide (alkaline) and hydrochloric acid (acidic).

2.1. Sample preparation
The mild steel specimens were cut into dimensions of 7 cm x 3 cm and polished with abrasive papers to remove dust, stains and any oxidation films on its surface. The 27 cut samples of mild steel were weighed before and after the immersion test and the data were recorded.

2.2. Aggressive medium preparation
The aggressive corrosion mediums were divided into three different aqueous solutions of near neutral, alkaline and acidic solutions. The near neutral solution was prepared by adding 35 g of sodium chloride in 1 litre of water, the alkaline solution was prepared by adding 40 g of sodium hydroxide in 1 litre of water, and the acidic solution by adding 36 mls of hydrochloric acid in 1 litre and using 100 mls of the prepared aqueous solution.

The 27 test samples were separated into 9 samples each and carefully immersed into the beakers containing the different corrosive mediums for 1, 3, and 5 weeks in order to observe the weight loss, hardness and surface roughness of the metal in this three environments.

The characterization of the mild steel test samples were by optical microscope to observe the surface morphology, the weight loss analysis technique for the immersed samples and surface roughness of the specimens.

3. Results and discussion
3.1. Weight Loss of Mild Steel
Figure 1, shows the weight loss graph of mild steel immersed in three different aggressive corrosion mediums of NaCl, NaOH, and HCl for 1 to 5 weeks duration.

The results obtained shows that the mild steel samples experienced weight loss in all the aggressive mediums it was exposed to.

For one week immersion test the mild steel specimens experience weight loss of 0.141 g for HCl test solution, 0.026 g for the NaCl solution, and 0.121 g for the NaOH solution. The acid solution produce the highest weight loss for the first week due to the presence of H+ ions and the Cl- ions which leads to severe attack on the mild steel surface.

As the immersion test of the mild steel samples are increased for three and five weeks more weight loss is further experienced by all the three aggressive mediums.

The data obtained for week three and five weight losses shows 0.082 and 0.163 g from NaCl solution, 0.211 and 0.273 g from NaOH solution, and 0.213 and 0.275 g from HCl solution.
3.2. Mild steel hardness
Figure 2 shows the hardness test result of mild steel samples immersed in three aggressive mediums.

![Graph of hardness test result of mild steel immersed in three aggressive mediums.]

Figure 2. The graph of hardness test result of mild steel immersed in three aggressive mediums.

The graph shows the decrease in hardness of mild steel against time (week) in different corrosion mediums. Mild steel without solution immersion test have hardness value of 157.2 hrv. The other samples immersed in the aggressive solutions shows the decrease of hardness which starts at 143.5 hrv for the NaCl, 140.0 hrv for the NaOH and 140.7 hrv for the HCl for the first week. The third week of hardness testing from the immersed samples indicates slight decrease in the hardness value. The NaOH solution records 138.5 hrv for the hardness value and 138.7 hrv for HCl. The NaCl solution showed a decline in the first to third week at 143.5 hrv to140.4 hrv, but in the fifth week it decreased slightly to 140.0 hrv. The HCl solution shows a very drastic drop from 140.7 hrv to 134.2 hrv when
compared to others. It is clear that the acid and the alkaline solutions affect the hardness strength of the mild steel more when compared to the near neutral solution.

3.3. Surface roughness of mild steel

Figure 3 shows the surface roughness comparison of the mild steel immersed in the aggressive mediums for 1, 3, and 5 weeks. All the data obtained for the three solutions showed an increase in surface roughness for all the specimens. Mild steel without immersion in a solution indicates the level of surface roughness value to be 0.311 μm. This is due to its surface not being exposed to elements that can speed up oxidation process on the surface of the mild steel. The graph shows the mild steel surface roughness from the NaCl solution for the first week increased, and the surface roughness rate of mild steel starts at 5.006 μm, and NaOH records 1.365 μm for the surface roughness, and 4.070 μm for the HCl solution. Surface roughness of the mild steel samples from NaCl solution shows the highest rate when compared with NaOH and HCl solutions. The surface roughness rate of mild steel for NaOH solution increased from 1.365 μm in the first week to 2.022 μm in the third week and 2.500 μm in the fifth week. While the surface roughness recorded for mild steel in the HCl solution shows an increase from 4.07 μm for the first week to 6.022 μm in the third week, and 10.525 μm in the fifth week.

![Figure 3. The graph of surface roughness of mild steel.](image)

It was observed that the NaCl solution gave the highest value for the surface roughness probably due to the rapid chloride ion attack on the mild steel surface. The rate of surface roughness of mild steel in NaCl increases from 5.006 μm for the first week to 7.206 μm in the third week, and 16.784 μm in the fifth week.

3.4. Surface morphology

Figure 4 shows the surface morphology of mild steel before and after immersion test in HCl solution for 1, 3 and 5 weeks.

The other surface morphologies from NaCl and NaOH as observed by the optical microscope produce similar micrographs to the HCl solution and only HCl solution is shown here. Figure 4 (a) shows surface morphology of the mild steel without immersion in the HCl solution. The surface is observed to be clear and free from any corrosion product. After immersion for 1 week Figure 4 (b) shows different surface coloration which starts to appear on the surface of the metal at a rapid rate. The color indicates the presence of rust from the electrochemical oxidation process. As the immersion
is prolonged Figure 4 (c) and (d) indicates continuous presence and spreading of rust which grows with prolong exposure to the corrosion medium.

![Image of mild steel morphologies](image-url)

**Figure 4.** Morphologies of mild steel after immersed in HCl solution for various periods. (a) No immersion (b) 1 week (c) 3 weeks (d) 5 weeks.

### 4. Conclusions

Steels find use in many application areas and this has made it a material of choice in many structural applications. The mild steel test samples exposed to three aggressive mediums corrodes as the attack on its surface becomes severe with time. The weight loss analysis as observed shows reduction in the weight for all the different mediums and with prolonged exposure the weight continues to reduce. The hardness test result also confirms reduction in the hardness as the exposure is prolonged. This investigation shows that mild steel cannot withstand aggressive mediums because the attacks are severe with loss of weight and hardness strength. The surface morphology also indicates high surface roughness from the corrosion products.

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### Acknowledgements

I would like to express my gratitude to Universiti Malaysia Perlis (UniMAP) and Center of Excellence Geopolymer and Green Materials (CEGeoGTech) for giving me the opportunity to be involved in this project.