Effect of sea water on some metals (Iron - Copper - Aluminium)

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ملخص البحث:

يعد التأكل من المشاكل التي تحدث للمنشآت الهندسية والصناعية و خاصة لبعض أجزاء المكائن والمعدات بعد تصنيعها وعند الاستخدام نتيجة لتعرض المعدن للوسط الأكل ، من أهم المعادن التي تتعرض لهذه المشكلة هي الحديد والنحاس والالمونيوم . لذا تم اعتماد هذه المعادن الأكثر استخداما في الصناعة لتكون موضوع الدراسة وهي (الحديد ، النحاس ، الألمونيوم) . وأخذت عينات من هدة المعادن وتم تجهيزها وذلك باستخدام القطع والتجليخ والتنظيف وكان وسط التأكل المستخدم في هذا البحث ماء البحر. حيث تم تحديد زمن التعرض لوسط ماء البحر (30،60،90،120) يوم ، وباستخدام طريقة الوزن المفقود لمعرفة معدلات التأكل والمقارنة بين النتائج المتحصل عليها . وقد تبين في هذا البحث أن معدل التأكل السنوي في وسط ماء البحر لمجموعة معادن وهي (الحديد، النحاس، الألمونيوم) أن أعلى معدل تأكل كان في معدن الحديد ويليه النحاس ثم معدن الالمونيوم ويزداد التأكل بزيادة زمن التعرض . وتم استعمال عينات اسطوانية الشكل وأوعيه حجم 250مم مملوءة بماء البحر، واستخدم بعض الأجهزة المعملية كالميزان الحساس والدورق.

الكلمات المفتاحية : الحديد ، النحاس ، الالمونيوم ، ماء البحر ، التأكل

Abstract

Corrosion is one of the problems that occur to engineering and industrial facilities, especially to some parts of machines and equipment after their manufacture and when used, as a result of exposure of the metal to the corrosive medium. The most important metals that are exposed to this problem are iron, copper and aluminium. Therefore, these metals most used in industry were approved to be the subject of the study, namely (iron, copper, aluminum). Samples of these metals were taken and prepared using cutting, grinding and cleaning. The corrosive medium used in this research was sea water. The exposure time to sea water was determined as 30,60,90 and 120 days. The lost weight method was used to find out the rates of corrosion.

In this study, it was found that the annual corrosion rate of sea water for the selected metals is that the highest corrosion rate was in iron metal, followed by copper and then aluminium, and the corrosion increases with increasing of exposure time. The tested samples were cylindrical in shape. They were put inside containers of volume 250 mm^3 filled with sea water. Some laboratory equipment such as a sensitive scale and beaker were used.

Key words: iron, copper, aluminium, sea water, corrosion.

1.Introduction

1.1. Corrosion phenomenon

Corrosion is one of the most important problems facing the industry field, which leads to erosion of the surface of the metal parts by the corrosion medium, which results in the damage and failure of the metal parts and sometimes leads to stops, commissioning and maintenance[Al-Mousawi, K.A.2000]. There are several forms of corrosion, including general corrosion, pit corrosion, galvanic corrosion, inter-gap corrosion, and bacterial corrosion [Bagni I. M.,2006].

Most of the corrosion processes are of an electrochemical nature that arises from the occurrence of interactions on the surface of metals. Corrosion causes annual losses estimated at millions of dollars. It is also turns new facilities into broken structures, machinery and engines into unusable piles [Biola, O. and Oforka, M, (4),2,111-117,2014].

The phenomenon of corrosion is considered to be of importance and has become one of the important disciplines of engineering study and research.

1.2. The importance of metals and their uses

Metals are of great importance, as they are used sufficiently in our live, whether they are in industry, wearing them, or owning them. As mentioned above the three selected metals have many varieties of use including their use in sea water. Iron is the most widely used metal in various fields, including iron bars, ships, bridges, automobile industry, gas pipelines, and other uses [Al-Mousawi, K.A.2000]. Copper is also used in several areas, including in the manufacture of high-pressure water heaters, sea water pipes, electric power plants and water desalination plants. And the common uses of aluminium are in the manufacture of automobiles spare parts, manufacture of aircraft and ships, and in plants structures as distillation of sea water stations.

1.3. Previous studies

Corrosion are closely related to the quality of the material subject to erosion and the quality of the corrosive medium. There are a large number of corrosive media from which different types of erosion appear. For a specific metal, it is necessary first to precisely analyze each of the medium and the metal to determine the nature of corrosion that it will cause, and accordingly deduce the ways to protect from. Because of the importance of carbon steel and its uses in several different environmental media and in industrial construction, there are many published papers on the study of corrosion and the effect of corrosion time and rates [Yahya N. A., etal,2019].

Khaled Al-Sharif and his colleagues studied the effect of fresh water, sea water and rain water on the corrosion rate and used a set of samples of steel iron, which were immersed in aqueous media during a time 60-240 min. at temperature 20-40 C^{o}. By using the lost weight method, the corrosion rates were calculated, as it was concluded that the corrosion rates of iron samples in sea water were the highest compared with the corrosion rates of fresh water. This is because of that salt water is a medium in the electrochemical reaction [Corvo, F.J (2007), , 47(4) p. 883-892.].

Hind Hammoud Al-Rashoud studied the corrosion of three samples of aluminium in sea water. This study was conducted using the lost weight method under different conditions. The results showed that the corrosion rate of the aluminium samples decreases with the increase of immersion time. The results also showed that the mechanism of corrosion of aluminium samples is carried

out through two processes according to the model (bi-modal), the first is the occurrence of corrosion under anaerobic conditions where the cathode process is oxygen reduction and the rate of corrosion is controlled by the diffusion of oxygen through the layer of corrosion products, and the second is in which corrosion occurs under anaerobic conditions and the cathode process is hydrogen reduction and is controlled by hydrogen diffusion[Rushoud H. H.,2018].

1.4. Preparation of test samples

The samples are prepared as following:

1-Pieces of iron, copper and aluminium were chosen.

2-The mechanical operations that included cutting and grinding were carried out to get the final shape which was cylindrical samples with different dimensions as shown in the figure below.

3- The samples were cleaned using iron brush.

4- After cleaning and cutting operations, the pieces were washed with distilled water and dried using an electric dryer, and each sample is weighed separately by a sensitive balance and labelled on each a sample.

5- The samples were classified so that they are close in weight and the sample number is written on its container as shown in figure (1,2,3) and table (1).

Fig. (1): Iron samples before immersion

Fig. (2): Copper samples before immersion

Fig. (3): Aluminium samples before immersion

Table (1): weight of samples before immersion in sea water

Immersion time	Sample no.	Metal	weight (g)
30 days	1	Iron	41.86
	1	Copper	36.32
	1	Aluminium	11.63
60 days	2	Iron	41.98
	2	Copper	36.34
	2	Aluminium	11.63
90 days	3	Iron	39.59
	3	Copper	36.40
	3	Aluminium	11.66
120 days	4	Iron	41.21
	4	Copper	36.93
	4	Aluminium	11.50

2.1. Samples Testing

- First time period: thirty days (720 hours).

- Second time period: sixty days (1440 hours).

-Third time period: ninety days (2160 hours).

-Fourth time period: one hundred and twenty days (2880 hours).

3-2 Corrosion medium:

Salt water: Salt water was obtained directly from the sea of Zliten.

4-2 Method of Testing

The corrosion test was conducted for the samples prepared previously by immersing them in the corrosion medium (sea water) in the glass containers horizontally and leaving the containers isolated from oxygen (closed). After the period of exposure, the samples were taken out of containers and cleaned from rust using a brush and distilled water, then dried with an electric dryer, and finally each sample was re-weighed to find its final weight for calculating the lost weight, which is the difference between the initial weight (weight of the sample before conducting the test) and the final weight (weight of the sample after conducting the test and removing corrosion residues) as shown in table (2).

Table (2): The weight of each sample after immersion and corrosion removal

Immersion time	Sample no.	Metal	weight (g)
30 days	1	Iron	41.82
	1	Copper	36.31
	1	Aluminium	11.63
60 days	2	Iron	41.86
	2	Copper	36.32
	2	Aluminium	11.63
90 days	3	Iron	39.36
	3	Copper	36.40
	3	Aluminium	11.65
120 days	4	Iron	41.08
	4	Copper	36.89
	4	Aluminium	11.49

2.5. Results and discussion

To calculate the lost weight of the test samples, the weight loss method was used to calculate the erosion rate, which is the most used method and it is called the weighted method. It is widely used to find the general erosion rates.

The steps used to measure the rate of erosion by weight loss method are:

a - The samples were prepared with cylindrical geometric shapes.

b- Weighing the samples with a sensitive scale and calculate their original weight (W_0) in milligrams.

c. Calculate the surface area exposed to the corrosion medium (A) in (cm^2).

d- The samples are immersed in the corrosive medium for a period of time (T) measured in days until erosion occurs.

e- Samples are removed from the corrosive medium, cleaned of corrosion residues with a brush, washed with water and dried with an electric dryer.

f- The weight of the samples after immersion is measured (W), then the change in weight is calculated. The lost weight is calculated by using the following equation:

Lost weight (ΔW_i) = weight of the sample before immersion - weight of the sample after immersion

$$\Delta W_i = W_0 - W$$

Table (3): The relationship between the lost weight and immersion time

Immersion time (days)	Sample no.	Lost weight (g)		
		Iron	Copper	Aluminium
30	1	0.04	0.01	0.0
60	2	0.12	0.02	0.0
90	3	0.13	0.04	0.01
12	4	0.13	0.04	0.01

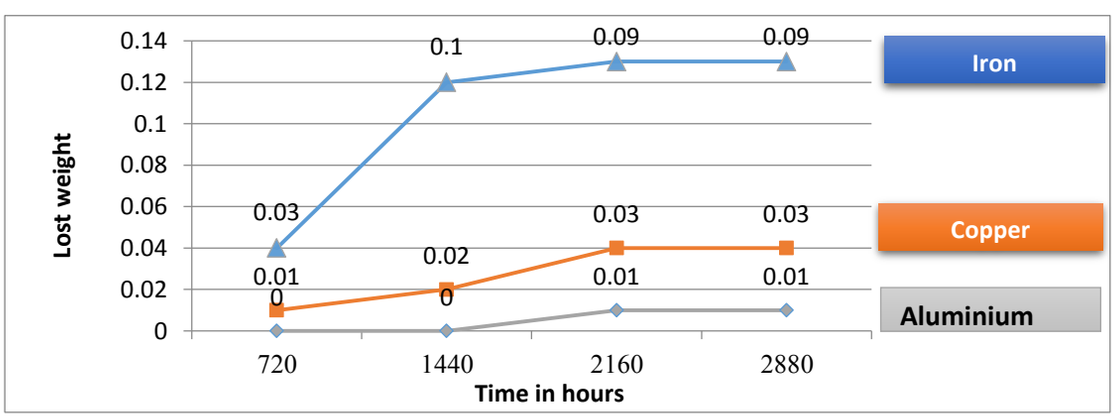

Figure (4): The relationship between the lost weight and time

Figure (4) shows the relationship between time and the lost weight of iron, copper and aluminium. It is clear that the highest rate was in the fourth month due to the long period of exposure to the corrosive medium (sea water). The

results showed that the lowest rate was in the aluminium sample, and the highest rate was in the iron sample.

2-6 Calculating the rate of corrosion

The unit of measure of (rate of corrosion) is in millimetres per year and written as (mm/y). Depending on the main function, which is the loss in weight (ΔW) during the test period (T). The test constants are: density of the metal (D), the area subjected to corrosion (A). The following equation was used to calculate the rate of corrosion [spotlights/6180_pg87-118 web.pd]

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

Where; *CR* is the rate of corrosion in (mm/y), *K* is constant equals to 87.6 to let the rate of corrosion measured in (mm/y), ΔW is the lost weight measured in (mg), *D* is the density of metal in g/cm^3, *A* is the exposed surface area in cm^2 and T is the exposure time in hours.

The lost weight is calculated by using the following equation:

Lost weight (ΔW_i) = weight of the sample before immersion - weight of the sample after immersion

$$\Delta \mathrm{W_i} = \mathrm{W_0} - \mathrm{W}$$

The exposed surface area is calculated by using the equation;

$$\mathrm{A} = 2 \times \pi \times \mathrm{r}(\mathrm{r} + \mathrm{h})$$

Where, *h* is the sample length, *r* is the sample radius, π is a constant equals 3.14.

- Calculating the rate of corrosion of iron sample during a month:

1- Surface area of the sample

$$\mathrm{A} = 2 \times \pi \times \mathrm{r}(\mathrm{r} + \mathrm{h})$$

$$= 2 \times 3.14 \times 0.65(0.65 + 4) = 19\ cm^2$$

2- Annual corrosion rate

$$\mathrm{CR} = \frac{87.6 \times 40}{7.874 \times 19 \times 720} = 0.03252\ \mathrm{mm/y}$$

- Calculating the rate of corrosion of copper sample during a month:

1- Surface area of the sample

$$A = 2 \times 3.14 \times 0.6(0.6 + 3.3) = 14.69 \text{ cm}^2$$

2- Annual corrosion rate

$$CR = \frac{87.6 \times 10}{8.96 \times 14.69 \times 720} = 0.00924 \text{ mm/y}$$

- Calculating the rate of corrosion of aluminium sample during a month:

1- Surface area of the sample

$$A = 2 \times 3.14 \times 0.6(0.6 + 3.2) = 14.32 \text{ cm}^2$$

2- Annual corrosion rate

$$CR = \frac{87.6 \times 0}{2.7 \times 14.32 \times 720} = 0.0 \text{ mm/y}$$

The other values of the samples can be calculated by using the same equations.

Table (4): annual rate of corrosion of the samples

Immersion time	Iron corrosion rate (mm/y)	Copper corrosion rate (mm/y)	Aluminium corrosion rate (mm/y)
30 days (720 hrs.)	0.03252	0.00924	0.0
60 days (1440 hrs.)	0.04881	0.00924	0.0
90 days (2160 hrs.)	0.03863	0.01190	0.01022
120 days (2880 hrs.)	0.02766	0.00901	0.00787

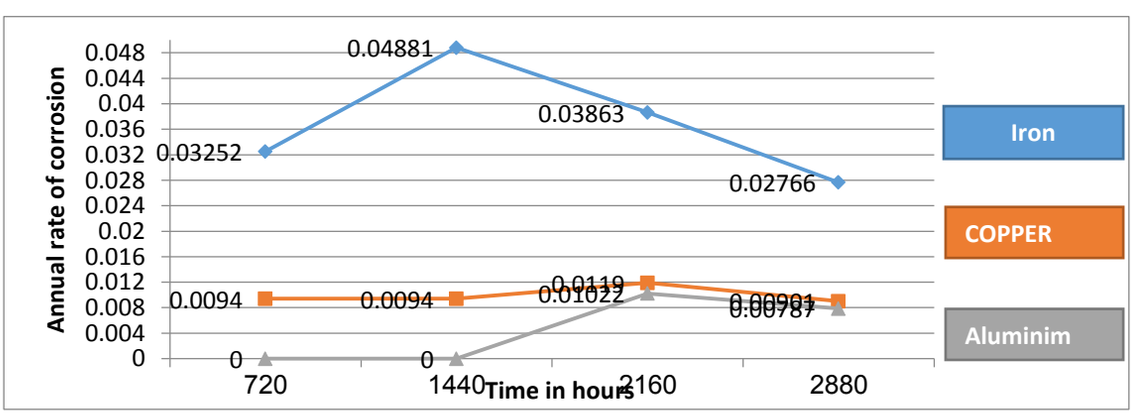

Fig. (5): The relation between annual rate of corrosion and time in hours.

In figure (5), the relation between rate of corrosion and time in hours shows that the maximum corrosion rate of iron was in the second month, and for copper and aluminium was in the third month whereas the minimum annual corrosion rate was in the fourth month for iron and copper, but for aluminium was in the first and second month.

7- Conclusion

Through the study that was conducted in this research, we conclude the following:

* The rate of weight loss increases in copper, iron and aluminium with the increase in the exposure period. The highest rate of corrosion was in iron, followed by copper and then aluminium.

* The lowest rate of weight loss was obtained in the samples during the exposure time of thirty days, and the highest rates were obtained during an exposure period of one hundred twenty days.

* The highest rate of corrosion of iron was obtained in the second month, and in the third month for copper and aluminium. The lowest rate of corrosion of iron and copper was in the fourth month. The corrosion resistance to rust increased with the increase of the exposure time and due to the formation of a film or layers of corrosion residues such as oxides. The lowest rate of aluminium was in the first and second month due to the resistance of the metal.

* After removal of the samples, it was found that the type of corrosion is regular.

References:

1- Al-Mousawi, K.A. Cameras, ENGA Publications, Malta (2000).
2- Bagni I. M., Basics of Corrosion Engineering, National Book House, Benghazi (2006).
3-Biola, O. and Oforka, M. “Inhibition of the corrosion of mild steel in hydrochloric acid by (4-amino-2-methyl-5-pyrimidinyl methylthio) aceticacidan its precursor” American Journal of Materials Science (4),2,111-117,2014.
4-Kobelco: Copper alloy tubes for heat-exchanger; Shinko Metal product,japan :http://www.shinkometal.co.jp/catalog/copper alloy-en-sc.pdf.
5-http://www.asminternational.org/pdf/spotlights/6180_pg87-118 web.pd

6- Yahya N. A., etal, Effect of different aqueous media on the corrosion behavior of medium carbon steel, Department of Mechanical and Industrial Engineering Zawia University 2019.

7- Corvo, F.J (2007), etal, Changes in the rate of atmospheric erosion caused by chloride ions depending on the rain System, corrosion science, 47(4) p. 883-892.

8- Rushoud H. H., Study of corrosion inhibition behavior of some aluminium alloys. a MSc. thesis entitled, Sea Water, 2018.