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Effect of pH and salinity upon the corrosion rate of Marine vessel structure surface

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Abstract
In this study, a lab conducting experiments were performed for detecting corrosion behavior of mild carbon steel which is used in surface bodies of marine vessels. Corrosion for carbon steel was investigated by measuring the weight loss and hence the corrosion rate in four different media:1- tap water, 2- sea water, 3- acidified sea water, and 4- basified sea water. Those media were differ in their pH and salinity. The experiments were lasted for forty days, after that weigh loss were measured and corrosion rates were calculate, Moreover, the corroded metals in each media were measured by Atomic Absorption Spectrophotometer. The most effected surface was that immersed in acidic and saline medium which recorded the highest weigh loss of 2.344 mg and corrosion rate of 7.6684 mmy compared to 2.0124 mg and 3.073 mmy respectively for tab water medium.

Keyword: corrosion, vessels, carbon steel, marine environment, acidic, basic, saline

Introduction

Mild carbon steel is a major utilize in most structural shape such as vessels and surface plates, most metals are inherently unstable and could be corroded to create a major problems in industries [1]. As well as geomatrical structures of marine vessels [2].

In the marine transportation industry, for material cost's sake, some large vessels are made of carbon steel, i.e. ships, barges, tugs, etc. In order to protect these vessels from corrosion their hulls are covered with layers of specialized paints, industrial-sized sacrificial anodes are bolted to their hulls, and/or they may be alternately protected by way of an automatic "impressed current cathodic protection system". But as pleasure craft owners most of the types of metals that we find on our vessels are usually of higher quality, such as Austenitic stainless steels, different series of aluminum, bronzes of different alloys, and metals. What is surprising is that there are many types of metals which do not corrode. This is untrue and unfortunately this mistaken belief has proven to be very costly [3].

Chemical interaction of metals with environment leads to deterioration of materials which is called corrosion. Surfaces of all metals but gold are covered with oxide films. In aqueous solutions, the oxide film tends to dissolve, if the solution is acidic, the oxide film is dissolve completely leaving a bare metal surface as an active site. In neutral solutions the solubility of oxides will be much lower than in acidic solution [4].

Corrosion has a great effects upon metal structure surface mainly in reduction of metal thickness leading to loss of mechanical strength and structural failure or breakthrough and consequently leading to hazardous or injuries to people in touch.

Weight loss is a major results of corrosion in metallic surface bodies. It depends upon pH, at lower pH the loss increase with time, but weight loss increased slightly with time at basic solution [5]. Under control conditions of pH, the corrosion rate of carbon steel could be reduced [5]. Sea water of Arabian Gulf has a great effect upon the construction materials in desalination plants which are effected to a certain degrees of corrosion due to the effect of saline water with certain TDS values [6] which are represented as severe or aggressive environment.

Corrosion by sea water, which is known as aqueous corrosion, is an electrochemical process, and all metals and alloys when in contact with sea water have a specific electrical potential (or corrosion potential) at a specific level of sea water acidity or alkalinity-the pH.

Corrosion of metal contents could be controlled by the additives of small amounts of chemical compounds, known as corrosion inhibitors control, an inhibitors for carbon steel corrosion are potassium chromate [1]. Aqueous extract of parts of these inhibitors which have been used as palm tree [2]. and Zizyphus Spina-Chritisi extract [7].

Materials and Experiments

This study was conducted in laboratory basis by employing tanks of 10x20x10 cm3 dimensions filled with solutions of different salinity and pH. Casting steel which is used in the construction of marine vessels was used as plates pieces with certain sizes and properties were immersed in each solution separately in the above tanks and expressed in table 1. Four pieces of casting steel, cleaned, weighted and all dimensions were measured and each was put in four separated aqueous solutions of different corrosion actions represented by acidic, basic, neutral as well as pure sea water with different properties of pH and EC. The casting steel pieces were left in the solutions for 40 days, then all were lifted from the solutions and weighted from which weight was calculated, and the solutions were prepared for trace elements analysis by Atomic Absorption Spectrophotometry

Table 1: Properties of solutions used for Immersion of casting steel.

Parameters	Type of solutions			
	Acidic	Basic	Tap water	Sea water
Sample	Casting steel	Casting steel	Casting steel	Casting steel
pH	2.24	12.7	7.13	6.87
EC, mS/cm	134.1	1 61.8	3.55	166.5
Salinity ‰	44.36	44.25	3.1	45.9

Results and Discussion

Steels are the most extensively used structural materials in manufucturing marine vessels. In corrosive environment, steel structures can be saved by coating and/or cathodic protection [6]. In marine or seawater environment, steel may not withstand. Typically, measurable Corrosion experiments involving mild (demineralized water) or aggrisive (marine and seawaters) conditions.

The effect of acidic/basic function and TDS on the corrosion behaviour of carbon casting steel investigated in filtered water, raw water and demineralized water.

Metal resistivity to corrosion in each solution is measured quantitivly by adopting the corroision rate which could be calculated in different wayes among which is the most simple weigh loss measurement adopted in this study [2].

Pieces of casting steel used in the four tanks were of the same type. After forty days of immersion in the selected solutions, weight loss of each piece of plate was estimated and the corrosion rate of casting steel in each medium was calculated and listed in table 2 together with the corrosion rate which was estimated following the procedure of Rajeh *et al*. (2008) [2], while trace elements analyzed in each of the solutions are determined and listed in table 3.

Table 2: Wight loss and corrosion rate for casting steel in different media.

Medium	Weight loss(mg)	Corrosion rate(mmy)
Fresh water	2.0124	3.0730
Sea water	2.1630	6.0730
Basic	2.0188	5.6502
Acidic	2.3244	7.6684

It can be seen that the maximum weight loss was in the medium of acidic, low pH value of 2.4. Moreover, the corrosion rate was high in the see water medium with high salinity [5].

Table 3: Measurable trace elements corroded from casting steel in different media.

Trace elements	Nature of the solutions				
	Acidic	Basic	Tap water	Sea water	Control
Cd	0.036	0.108	0.101	0.029	0.0218
Cr	1.102	0.495	0.820	0.651	0.0250
Co	0.344	0.143	0.122	0.340	0.1412
Fe	4.983	0.905	1.241	0.955	0.391
Mn	0.962	0.058	0.455	0.175	0.0252
Ni	2.164	1.545	0.337	2.305	1.034
Pb	0.012	0.020	0.013	0.032	0.0888
Zn	0.133	0.055	0.031	0.045	0.0162

According to table 3 it seems that most of the weight loss was due to the corrosion of trace elements which estimated to be the largest in the acidic, comparable for both see water and tap water, but it was lower for basic medium. Moreover, the most corrosive metals were Fe (4.983) followed by Ni (2.164) and Cr(1.102)in the acidic medium. On the other hand the lowest corroded metal were Cd (0.036), and Pb(0.012)in Acidic medium.

Moreover, data in table 3 show that at sea water, Ni and Fe metals have high corrosive abilities for casting steel compared to all other estimated metals, Cd, Cr, Co, Mn, Pb, and Zn. Therefore, in order to prevent corrosion of marine vessels made of carbon steel their bodies should cover with a thin film of metals alloy [8, 9].

Water that is soft and pH<7 classified as more corrosive but the generally accepted measures of water corrosively are the stability or saturation indices, the chemical characteristics of water such as hardness and pH [10].

The rate of corrosion was higher in sea water of Arabian Gulf compared with fresh water of Shatt Al-Arab River [11]. Corrosion by sea water is an electrochemical process, and all metals and alloys when in contact with sea water have a specific electrical potential(or corrosion potential)at a specific level of sea water acidity or alkalinity - the pH. Sea water, by virtue of its chloride content, is a most efficient electrolyte. The omni-presence of oxygen in marine atmospheres, sea spray and splash zones at the water-line, and sometimes surprisingly at much greater depths, increases the aggressiveness of salt attack. This will explain why Ni is highly corroded in sea water which could be explain on the basis of stable Nickel chloride complex formation. The high loose of Ni metal in the Sea water medium of pH = 6.87 is show on in figure 1.

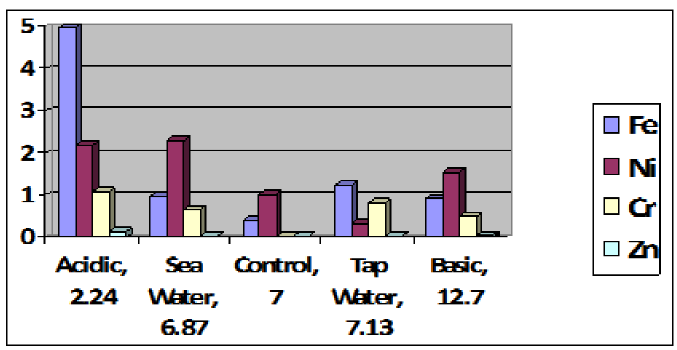

Fig 1: Concentrations of metal elements of casting steel loose in different pH of solution.

The differential concentration of oxygen dissolved at the water line or in a droplet of salt spray creates a cell in which attack is concentrated where the oxygen concentration is lowest. Crevices which allow ingress of water and chlorides but from which oxygen is excluded rapidly become anodic and acidic are hidden start point of corrosion. Weight loss for low carbon steel showed quite effective increase in value with time due to corrosion in each of tape water and acidic solution of 0.1 M HCl, while upon using anweight loss reduced with time [2]. As time increase, the weight loss of carbon steel surface is increased due to the nature of oxides in the surface of the steel which characterize with high porosity and weak attraction therefore it cannot protect the surface of the metals [2].

According to table 2, the maximum weight loss recorded was in the acidic medium which is explained on the basis of the presence of hydrogen ions which consume electrons and accelerate the corrosion rate through their transfer to atoms.

Some of the major harmful effects of corrosion can be summarized as follows:

1. Reduction of metal thickness leading to loss of mechanical strength and structural failure or breakdown. When the metal is lost in localized zones so as to give a crack- like structure, very considerable weakening may result from quite a small amount of metal loss.
2. Hazards or injuries to people arising from structural failure or breakdown (e.g. bridges, cars, aircraft).
3. Loss of time in availability of profile-making industrial equipment.
4. Reduced value of goods due to deterioration of appearance.
5. Contamination of fluids in vessels and pipes (e.g. beer goes cloudy when small quantities of heavy metals are released by corrosion).
6. Perforation of vessels and pipes allowing escape of their contents and possible harm to the surroundings. For example a leaky domestic radiator can cause expensive damage to carpets and decorations, while corrosive sea water may enter the boilers of a power station if the condenser tubes perforate.
7. Loss of technically important surface properties of a metallic component. These could include frictional and bearing properties, ease of fluid flow over a pipe surface, electrical conductivity of contacts.

Conclusion

The effect of different functions, acidity and salinity, on the corrosion behavior of carbon steel were different in fresh and saline as well as acidic or basic waters. In the laboratories, prevention of corrosion of mild carbon steel is proceeded as a small scale experiments by using natural products or certain chemicals, but for large marine vessels, the situation is different, it is recommended to prevent corrosion by change the contents of the mild carbon steel alloy used in construction of the vessel skeleton. Instead, another materials of the alloy represented by Cr, Mo., and N will influence the pitting and crevice corrosion behavior

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