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Aqueous Corrosion of Steel at Hooghly Stretch of Ganga River

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Abstract- Selection of material is most important factor to reduce the burden of wasted material, wasted energy and money in ship design. Generally ship structure faces many different types of destructive attack but aqueous corrosion is most troublesome in them. This paper focuses on aqueous corrosion of steel of ship structure and how chemical composition of water of Ganges river, affecting river going vessel at Hooghly stretches from Baharampur to Diamond Harbor.
Keywords- Aqueous corrosion, Chemical, Ganges river, Material, Ship construction.

I. INTRODUCTION

Common steel can be divided into two categories with respect to corrosion behaviour in marine environment; corrosion resistant materials which are coated with thin, tightly adherent, passive oxide film to limit the corrosion such as Aluminium, Stainless Steel, certain nickel base alloys and titanium, and corrosion allowance materials which usually corrode at high rate at favourable conditions such as Steel, Zinc, and Copper based alloys. It is an electrochemical reaction of metal in wet environment, resulting in the deterioration of metal and its valuable property.

II. AQUEOUS CORROSION

We can divide aqueous corrosion into eight common forms as follows; Uniform Attack, Pitting, Crevice Corrosion, Galvanic Corrosion, Erosion Corrosion, Environmentally Assisted Cracking, De-alloying, and Inter-granular Corrosion.

A. Uniform Attack

It is reduction of metal from metal, and it is also electrochemical in nature. The anodic reaction is metal oxidation while cathodic reactions are as follows; Oxygen reduction, water reduction, metal ion reduction, and reduction of an oxidant such as nitrate or H_2O_2. In wet environment, the dominant reduction reaction is oxygen reduction.

B. Pitting

As per corrosion literature, pitting can occur in two ways; Morphological mechanism in which pit propagates may be anything from erosion-corrosion to differential cell corrosion, and Mechanistic which is a localized corrosion, occurs mostly on exposed surface of passive metals under relatively stagnant condition. Besides these, pitting can occur on film free metals at local metallurgical imperfection such as at inclusions. The steps involve in pitting are as follows; metal oxidation within the pit, migration of anions, acidification in the region as a result of hydrolysis of the metal ions and Oxygen depletion once on occluded cell has formed. But it is true that pitting is varying depending on alloy system or environmental condition. Metallurgical factor which helps to propagate pitting is in-homogeneity in material, such as inclusion, segregation, welds, scrapes and heat-tinted areas. The environmental factors which initiate pitting are such as; presence of specific ions, presence of oxidizing conditions, and local difference of oxidizing strength of the environment.

C. Crevice Corrosion

This corrosion is like pitting corrosion. In presence of crevices and plentiful supply of oxygen under submerged condition, this corrosion propagates. The first stage involves the depletion of oxygen within the crevice and formation of differential aeration cell and reduction of passive films with in the crevices. The conditions favourable for promoting crevice corrosion are presence of crevice, and presence of deposits and fouling organisms. Presence of gaskets, washers and rivets also help to promote crevice corrosion.

D. Galvanic Corrosion

Galvanic corrosion, as its name implies, is the loss of material when it couples with dissimilar metal. If two metals, whose electrochemical potentials are different, are immersed in electrolyte then galvanic corrosion occurs. This type of corrosion of metal depends on its position in galvanic Series. A galvanic series is a series of different electrochemical potential material in flowing sea water at 25ºC. When electropositive metal is placed beside electronegative metal in electrolyte then corrosion of electronegative metal increases compare to electropositive metal. Galvanic corrosion depends on various conditions such as electrolyte conductance, electrical contact conductance, relative surface areas of the metal being coupled, and relative position of metals in galvanic series.

E. Erosion Corrosion

Erosion corrosion occurs due to the relative motion between corrosive media and metal surface. Cavitation is also an example of erosion corrosion. Cavitation caused by the formation of vapour bubbles and its collapse in a liquid near the metal surface. It occurs commonly in rotating machinery where high pressure drops encountered. This pressure drops can promote local boiling. The vapour bubbles which collapse can produce shock waves with very high pressure. This high pressure can cause plastic deformation of many metals. Erosion corrosion can be characterized by the presence of holes, grooves, or valleys which usually shows a directional pattern. Different kinds of adjectives are used to define erosion-corrosion, such as horseshoe, star, crescent and slot. The environmental factors which control the erosion corrosion are such as water velocity, Oxygen content, water pH, temperature, flow geometry, and presence of particulates in the water.

F. Environmentally Assisted Cracking (EAS)

It refers to a fracture or cracking of metal by the duel action of an applied strain and a specific corrosive medium. During EAS, the metal is almost corrosion free at surface but fine cracks progress through it. It is generally of three types; Anodic stress corrosion cracking occurs where there is an appropriate balance between electrochemical activity of the advancing crack tip and passivity of the crack walls and the free surfaces. Hydrogen stress cracking occurs during cathodic protection which facilitates hydrogen entry. Corrosion fatigue occurs due to dual action of corrosion and cyclic loading. Other factors which affect EAS are metal composition, heat treatment, solution composition, temperature, and stress related parameters such as stress intensity and cyclic loading. It is also true that one environmental condition which is promoting corrosion for one metal but same environmental condition is completely harmless for other metal.

G. De-alloying

It refers as selective removal of metal from an alloy, when it immerse in an electrolyte solution. There are two mechanisms which is promoting de-alloying. First one involves dissolution of the two alloying elements and the depositions of the more electropositive material onto the metal surfaces. The second one involves the surface diffusion and the selective dissolution of the active element.

H. Inter-granular Corrosion

It refers to localize attack of gain boundaries in certain aqueous environment. It is commonly observed in austenitic stainless steels where the attack is related to heat treatment in the temperature range of 500ºC to 800ºC. Heating the alloy in this temperature range promotes the precipitations of chromium carbides thereby removing the chromium from solid solution and resulting in a metal with lower chromium content than the adjacent areas.

III.SALIENT FEATURES OF GANGA RIVER BASIN

River Ganges is most sacred river to Hindu and this is the river which flows through nations Bangladesh & India. It is lifeline to millions of people whose are staying at bank of river. But it is also shocking to except the fact that it is fifth most polluted river of the world as per survey did in 2007.

Table 1: Average values of physio-chemical parameters of river Ganga

1.	T.S. (mg/l)	32-125
2.	T.D.S. (mg/l)	178-17167
3.	pH	7.2-8.1
4.	D.O. (mg/l)	6.7-8.5
5.	B.O.D. (mg/l)	5.2-37.6

6.	C.O.D. (mg/l)	5.2-37.6
7.	Alkalinity (mg/l)	108-164
8.	Hardness (mg/l)	96-2900
9.	Phosphates (mg/l)	0.233-2.292
10.	Nitrates (mg/l)	0.007-0.038
11.	Chlorides (mg/l)	9-9097
12.	TC (MPN/100 ml)	1100 x 10^5-16 x 10^5
13.	FC (MPN/100 ml)	20 x 10^5-1600 x 10^5

IV. IMPACT OF CHEMICAL COMPOSITION ON AQUEOUS CORROSION

A. pH Effect

The effect of CO_2 is related to acidification of the medium. Accumulation of OH^- ions in solution creates favourable conditions for formation of carbonate ions. The increasing concentration of CO_3^{2-} favours formation of $FeCO_3$ and gives rise to protective layers of siderite. The range of pH values of Ganges River is 6.5 – 8.1. At this range Steel will not corrode due to pH affects.

B. Dissolved Oxygen Effect

Oxidation of carbon steel is common phenomenon and it propagates uniform corrosion. Metal can be lost form exposed surface. This oxidation is generally called rusting. Due to rust material becomes thinner as it corrodes until its thickness is reduced to the point at which failure occurs. Oxygen affects the corrosion rate of metallic materials by providing a cathodic reaction. The range of DO values of Ganges River are 6.7 to 8.5 mg/l. These values are not sufficient for corrosion due to oxygen effects.

C. Effect Of Temperature

Corrosion of carbon steel increases due to temperature variations but polluted and unpolluted water plays major role in it. In unpolluted water the corrosion rate is directly proportion to oxygen concentration in water, which was highest during the winter when temperature and biological activities were minimum. In polluted water the corrosion rate is directly proportion to temperature. Generally oxygen concentration is low in polluted water. The mean temperature at Hooghly stretches is 31ºC. This temperature will not affect much for corrosion.

D. Effect Of Nitrate

Nitrate converted to ammonia by iron corrosion. This ammonia can affect iron corrosion by reacting with free chlorine to form chloramine. Ammonia is a better source of nitrogen than nitrate for most bacteria, so this triggers microbial growth and aqueous corrosion. The range of Nitrate values of Ganges River are 0.007 to 0.038 mg/l. These values are not sufficient for corrosion due to Nitrate affects.

E. Effect Of Pollution

In general pollution increases Sulphide contents, decreases concentration of oxygen and decreases pH values too. Sulphide is detrimental to the corrosion behaviour of steels. The polluted water is potentially very aggressive for corrosion. But in Ganges river Sulphide contaminant is less and it will not affect so much.

F. Effect Of Microorganisms

Microorganisms are found on Jetty, Pontoon and buoy. We can differentiate these bacteria in categories of Sulphate reducing bacteria, Iron bacteria, and Nitrifying bacteria. These bacteria can affect absorption of nutrients resulting in differential aeration and concentration of cell, liberation of corrosive metabolites, production of Sulphuric acid from more reducer sulphur compounds, and corrosion by anaerobic bacteria such as sulphate reducing bacteria.

V. CONCLUSION

In ship design common material for construction is plain carbon steel. It is selected because of its availability, low cost, ease of fabrication, design experiences, and physical and mechanical properties. The effect of aqueous corrosion is less in Ganges river. Corrosion occurs usually at a portion whose geometry is critical and at open deck where there is a possibility of rain water clog due to improper drainage system. But it is also true that aqueous corrosion is a natural phenomenon. It can happen any time. So it is better to take preventive measures to avoid unnecessary hazard such as painting or coating which will isolate corrode material from river water. We can use sacrificial anode to change the potential of metal at a point where corrosion occurs and corrosion inhibitors to transform metal to passive. These corrective measures will increase the cost of manufacturing but it is also fact that aqueous corrosion causes 30% of failures of ships and other marine equipment.

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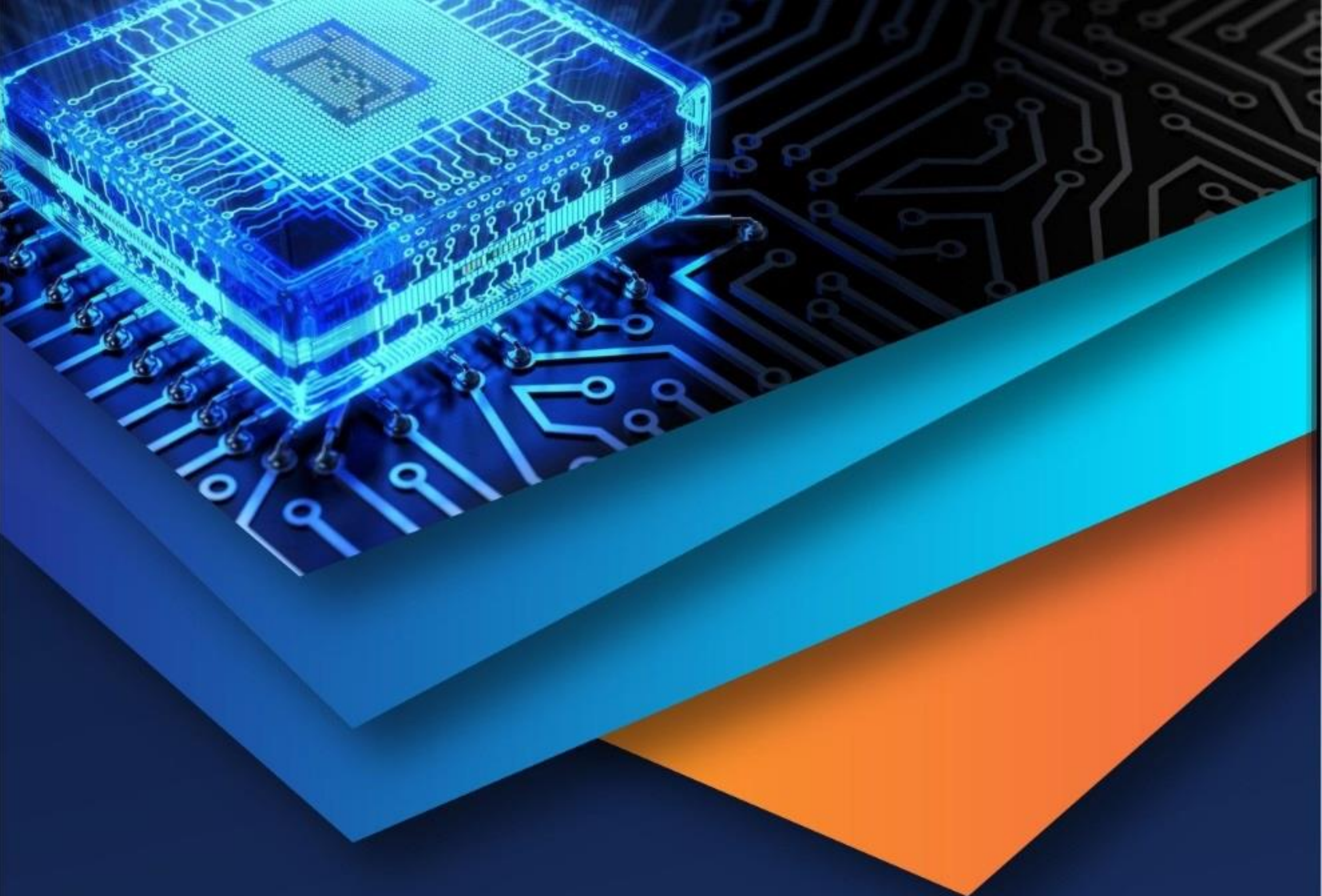

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