International Journal of Chemical Sciences and Applications
ISSN 0976-2590, Online ISSN 2278 – 6015
Vol 4, Issue 1, 2013, pp 7-11
http://www.bipublication.com

A STUDY ON IMPACT OF ATMOSPHERIC CORROSION ON DIFFERENT TYPES OF METALS

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[Received-07/12/2012, Accepted-07/01/2013]

ABSTRACT

In recent few decades, atmospheric corrosion of materials is considered as a major issue by most of the industries. Corrosion is occurred because of the degradation of the material due to the reaction of environment. The atmospheric corrosion causes more failures on both the cost basis and tonnage basis than any other environmental corrosion. Tremendous amounts of materials in automobiles, industries, bridges, buildings and constructions are exposed to the atmosphere and it is attacked by the pollutant and water. This study discusses about the atmospheric corrosion on different metals like copper, aluminium, brass, stainless steel, and galvanized Steel.

Index Terms: Corrosion, Atmospheric Corrosion, Materials and Metals

I. INTRODUCTION TO CORROSION

The term corrosion is derived from latin word "corrosus" that means consumed by degrees or eaten away; The term corrosion is an unpleasant word for the unpleasant process [1]. Corrosion is defined as destruction of materials by electrochemical or chemical action of surrounding environment. Corrosion is experienced in day-to-day living. According to Speller [2], the most common example for corrosion may include discoloration, tarnishing and rusting. Corrosion is considered as ever occurring material disease. It is possible to reduce the corrosion but it cannot be prevented. Corrosion will be slow or fast. Polythionic acid has capacity to attack sensitized 18-8 stainless steel badly in few hours.

Corrosion process can be classified into two types:

- Electrochemical Corrosion
- Chemical Corrosion

The following figure indicates the classification of corrosion

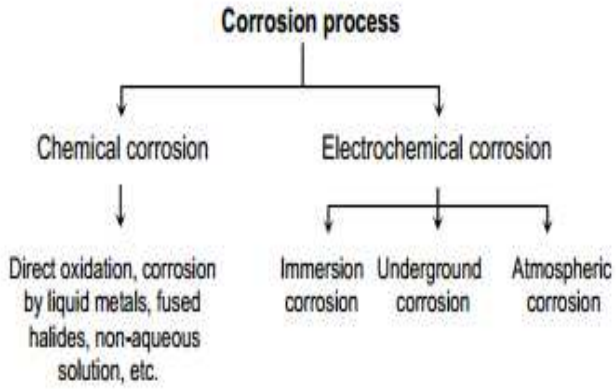

Figure: Classification of Corrosion Process
Source: Natesan M, (1995): PhD Thesis, Anna University, Chennai, India

Reaction of metals with oxygen or dry air is considered as the chemical corrosion. In addition to these, tarnishing of metals like silver, copper, etc and high temperature oxidation of the metals will fall into this category. This can also be considered as an electrochemical process with diffusion of metal ions (outwards) and oxygen (inwards) through oxide layer. Electrochemical corrosion occurs due to the presence of electrolyte. According to Evans and Hoar [3], the electrochemical corrosion is considered to occur at metal-solution interface due to the creation of local anodic and cathodic sides on metal surface.

II. ATMOSPHERIC CORROSION IN VARIOUS MATERIALS

Carbon steel (cold and hot rolled) is one of the most widely used metals for the outdoor applications. In addition to these, some of the materials like stainless steel 304, copper, aluminum, brass and galvanized steel are used in larger quantities for outdoor applications.

The following figure illustrates the nature of corrosion products that formed on four metals.

	Common species	Rarer species
Al	$Al(OH)_3$ Al_2O_3, $Al_2O_3, 3H_2O$	$AlOOH$, $Al_x(OH)_y(SO_4)_z$, $AlCl(OH)_2.4H_2O$
Fe	Fe_2O_3, $FeOOH$, $FeSO_4, 4H_2O$	$Fe_x(OH)_yCl_z$, $FeCO_3$
Cu	$Cu_2O_1, Cu_4SO_4(OH)_6$, $Cu_4SO_4(OH)_6, 2H_2O$, $Cu_3SO_4(OH)_4$	$Cu_2Cl(OH)_3$, $Cu_2CO_3(OH)_2$, $Cu_2NO_3(OH)_3$
Zn	ZnO, $Zn_5(OH)_6(CO_3)_2$, $ZnCO_3$	$Zn(OH)_2$, $ZnSO_4$, $Zn_5Cl_2(OH)_8.H_2O$

Table: Nature of corrosion products that formed on four metals

Source: Roberge P.R, (1999): Handbook of Corrosion Engineering, McGraw-Hill, USA. 58.

a) GALVANIZED STEEL:

Galvanized steel is mostly used in power transmission lines, roofing, telecommunication industry, thermal power plant, siding and fencing and automotive industry [5,4]. In areas where SO_2 is present in any quantity, then the galvanized surface will be attacked. In areas where SO2 is present in any appreciable quantity galvanized surface will be attacked. The species in atmospheres will accelerate the corrosion of the galvanized steel by increasing the surface layer's conductivity after the dissolution of soluble ions. The effect of particles $(NH_4)_2SO_4$ is the reason for corrosion of galvanized steel.

The galvanized steel structures corrosion process begins through the electrochemical process, when the Zn surface becomes wet with dew, rain and mist [6]. A layer of basic zinc carbonate, $2ZnCO_3 3Zn(OH)_2$ forms on the galvanized steel structures in exposures (exceeding one year) [7,8]. This tends to inhibit Zn corrosion.

According to Haynie [9], Zn corrosion in steady state and long-exposure conditions as the linear functions:

$$C = A/B + Bt$$

where C = total Zn corrosion, µm

t = exposure time, y;

B = dissolution rate of the film, µm Zn/y; and

A = diffusivity of corrosive species through the film, $\mu m^2/y$.

The total Zn corrosion (C) is sum of Zn that contained in film (A/B) and Zn dissolved from film by precipitation (B). Diffusivity (A) will be affected by the atmospheric species. The dissolution rate (B) is determined by delivery rate of the acidic pollutants to film and also by the mineral phases that present in it. Wet and dry deposition delivery mechanisms will provide for describing the rate controlling mass that affecting corrosion of Zn coating.

b)STAINLESS STEEL 304:

Stainless steels 304 were first introduced about 70 years ago for commercial use. Stainless steel 304 is

used in fruit juice industry, dairy equipment, food processing applications such as in bakeries, mills, slaughter and packing houses, fermentation vats, dippers, dye tanks, hauling equipment and railroad cars. The considerable amount of information was accumulated about stainless steels 304 atmospheric corrosion behavior.

c) BRASS:

Brass is one of the metals that is widely used in engineering materials. It is possible to find brass applications in marine, air conditioning, construction and fabrication industries, electrical industries. $70/30$ brass has α phase structure and it is resistant to various inorganic and organic reagents. Anodic reactions for corrosion of the brass is dissolution of both Zn and Cu. In acidic medium, cathodic reactions are due to the reduction of the dissolved oxygen is to form the water and discharge of hydrogen ion is to form the nascent hydrogen. Reduction of nitrosonium ion will provide formation of the nitrous acid. The formation of nitrous acid and nitrosyl ion denotes the limiting stage of the cathodic reaction of reduction of nitrous acid. In the active species, nitrous acid makes the corrosion of brass and the concentration controls the dissolution $70/30$ brass in HNO_2 acid.

d)COPPER

Copper is one of the natural components in the most ecosystems and it is one of the metals that always found in most of the applications in modern and old societies. Today's the whole society is based on the electrical conductivity of metals to convey signal information and power electronic and electrical equipment, architectural and artistic. For these purposes, copper is considered as one of the most important metals. The use of copper in various and many applications besides conductors, for example as roofing material for the statues and decorative structures, there is a long time behavior of unsheltered copper outdoors causes atmospheric corrosion. For example, copper patina formation and its stages together with the mechanistic deliberations, are examined.

The general sequence of the corrosion of copper is known. Initially water and oxygen react with the fresh copper surface will form the sequential structure that consists of $Cu_2O\ /\ CuO\ /[Cu(OH)_2\ or\ CuOXH_2O$ and the main component of Cu_2O is cuprite. This is followed by the reaction with some pollutants that present as gases (for example: $SO_2, NO_2, O_2, Cl_2, HCl, and\ H_2S$) as the ions in precipitation or ionic constituents of the aerosol particles. Some of the important compounds that found in the patina constituents are: atacamite, $Cu_2Cl(OH)_3$, posnjakite and brochantitie in urban and rural areas. When the copper is used for the electronic signal transmission, some small defects on the contact surfaces due to corrosion will cause complete or partial failure of the device.

e) ALUMINIUM

Aluminum is one of the metals and it is most abundant elements in nature. Aluminum's high elastic modulus, its corrosion resistance, electrical and thermal conductivity, and its low density, and its capacity to form the alloys with several elements makes it as a most useful materials for the purpose of construction [10]. Generally, aluminum and its alloys will be black to grey staining when they exposed to atmosphere corrosion due to the rain or moisture on the surfaces [11,12]. The degree of staining will not depend on the water and staining rate is controlled by the diffusion rate of the oxygen into the film of water condensed [13].

When comparing with other metals, aluminum corrodes very slowly under the atmospheric conditions and this is because it will form insulating amorphous oxide film with low solubility in the air and also the aqueous solutions over the pH range from $4\ to\ 8.6$.

The following figure illustrates the average seasonal corrosion rate of the aluminium.

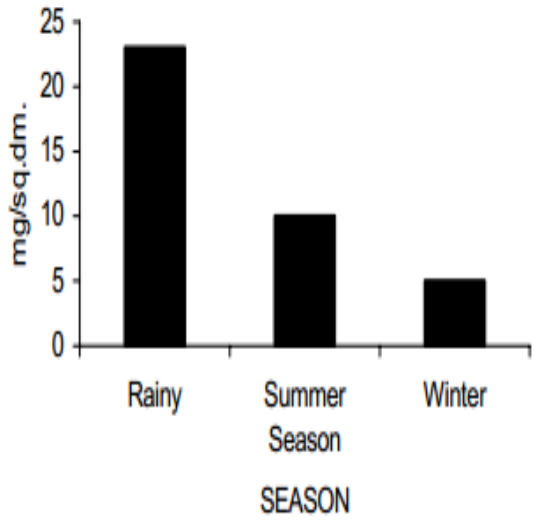

Figure: Average seasonal corrosion rate
Source: Vashi R. T, Malek G. M, Champaneri V. A and Patel R.N, (2002): Bull.Electrochem., 18:91.

The above figure clearly states that, the corrosion rate of aluminium is completely high in rainy season than other seasons. The corrosion rate of the aluminium in the rainy months $(22.7\ mg/sq.dm.)$ was greater than the corrosion rate in the summer months $(10.5\ mg/sq.dm)$ and the winter months $(6.5\ mg/sq.dm.)$.

f) CARBON STEEL

Outstanding in its weldability and drawability, hot rolled carbon steel is mostly used in the automobile frames, building structures, bridges, special vehicles, general structures, ships and wheels. Cold rolled carbon steel is mostly used in the low temperature toughness, fracture resistance, hydrogen-induced crack resistance, high formability and weldability. This steel is mainly used in the cold rolled products such as general pipes, GI, CR, colour plates, pipes for machines, structural pipes, special pipes, oil well pipes and high pressure gas cylinders [14]. The corrosion of carbon steel has prime interest for the electrochemist and the corrosion engineers and this is because, it is one of the widely used materials.

The following table illustrates the rating scale of the corrosion.

Rating	Surface appearance of plate	Weld appearance
0	No corrosion or staining	Unaffected
1	Staining and/or spot rusting (0-25%)	Minor corrosion
2	Discoloration and/or increased corrosion (25-75%)	Crevice attack and/or pitting corrosion visible
3	Corrosion over entire surface (75-100%)	Severe corrosion; cracking

Table: Rating scale for corrosion
Source: Boulton L.H, Miller N.A and Sanders M.C, (1988): Br. Corros. J., 23:117

III. CONCLUSION

It is concluded that corrosion of materials takes place due to the electrochemical or chemical action on the materials. The atmospheric corrosion of various materials such as stainless steel 304, hot and cold carbon steel, copper, galvanized steel, brass and aluminum is discussed in this study. This study concludes that all the metals have various capacity and stages to be affected by the corrosion. Most of the materials are affected by corrosion in rainy season rather than other seasons.

This study concludes that, in fact all the countries would be dramatically changed, if there is no corrosion. It is clearly understood that, most of the industries like automobiles, ships, house-hold appliances and underground pipelines are affected by corrosion in some various stages. In addition to these, construction industries are the one, which is mostly affected by the atmospheric corrosion. The atmospheric corrosion is considered as the most prevalent type of corrosion and it is mostly affecting the materials like metals.

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