

# Review of Marine Environmental Corrosion and Application of an Anti-Corrosive Coating / Painting System at Hull Portion

A.C. MARIAPPAN<sup>1</sup>, V. Janakiraman<sup>2</sup>, C. Kamaraj<sup>3</sup>

<sup>1</sup>Assistant Professor, Department of Marine Engineering, PSN CET, Tirunelveli, Tamilnadu

<sup>2</sup>Professor, Department of Mechanical & Automation Engineering, PSN CET, Tirunelveli, Tamilnadu

<sup>3</sup>Assistant Professor, Department of Marine Engineering, PSN CET, Tirunelveli, Tamilnadu

\*\*\*

## Abstract

Painting a ship's hull is one of the most expensive activities that are carried out during dry docking. Considerable amount of keenness and venture is required to ensure that the task is carried out in the most efficient manner.

Due to age of slow blistering, when ships have to comply with a series of environmental regulations, efficient hull coating and maintenance is of utmost importance. Loss of vessel speed from fouling also has huge fuel consumption and bunker fuel cost implications, which is directly proportional to the quality of hull paint and hull fouling control systems.

Acceptance sampling is an inspection procedure used to determine whether to accept or reject a specific quantity of material. It is a part of the operation management or of accounting, auditing and services of quality supervision. Acceptance sampling is most likely to be useful in the following situations:

- ✚ When the time and cost on 100% inspection is extremely high.
- ✚ When 100% inspection is not technologically viable.
- ✚ When there are many items or spots to be inspected and the inspection error rate is sufficiently higher than 100% inspection might cause a higher percentage of defectives (Low WFT Inspection) to be passed than would occur with the use of sampling plan.
- ✚ The design method of optimization is employed on any large area's anti corrosive coating / painting condition monitoring / inspection scope is to improve the quality level as well as minimizes the client's risk.
- ✚ Review of decision making to choose the right and real time of anti-corrosive painting system.

**Key Words:** NACE.

## 1. INTRODUCTION

### 1.1 Corrosion

Corrosion is the destructive attack of a metal by its reaction with the environment. A more scientific definition of corrosion will be given later in this paper, but the description just provided is a good working one. There are many different specific environments which are possible, depending upon how the particular metal is used. The most general case is that in which the environment is a bulk aqueous solution. For atmospheric corrosion, the aqueous solution is a condensed thin-layer rather than a bulk solution. Note that the word "corrosion" refers to the degradation of a metal by its environment. Other materials such as plastics, concrete, wood, ceramics, and composite materials all undergo deterioration when placed in some environment; but this text will deal with only the corrosion of metals. The word "rusting" applies to the corrosion of iron and plain carbon steel. Rust is a hydrated ferric oxide which appears in the familiar color of red or dark brown. With referring to Fig. 1.1, the steel rusts (and also corrodes), the non-ferrous metals such as aluminum, copper, and zinc corrode (but do not rust). The term "white rust" is often used to describe the powdery white corrosion product formed on zinc. The "white rusting" of sheets of galvanized steel (zinc-coated steel) is a frequent problem, if the sheets are stacked and stored under conditions of high relative humidity. Condensation of moisture between stacked sheets will often lead to "Red rusting".



Fig. 1.1

### 1.2 Physical Processes of Degradation

Metals may undergo degradation by physical processes which occur in the absence of a chemical environment. Physical degradation processes include the following:

- ❖ Fracture – failure of a metal under an applied stress.
- ❖ Fatigue – failure of a metal under an applied repeated cyclic stress.
- ❖ Wear – rubbing or sliding of materials on each other.
- ❖ Erosion or cavitations erosion – mechanical damage caused by the movement of a liquid or the collapse of vapor bubbles against a metal surface.
- ❖ Radiation damage – interaction of elementary particles (e.g., neutrons or metal ions) with a solid metal so as to distort the metal lattice.

### 1.3 Environmental Degradation

Each of the physical degradation processes above can be assisted or aggravated in the presence of an aqueous (Sea water) environment. Thus, corresponding to each of the degradation processes listed immediately above are environmentally assisted counterparts, as given in **Table 1.1**. In each case, metal degradation is intensified by the conjoint action of the physical process and the chemical environment.

Description	Flaw	Affected Area
Fracture	Stress-corrosion cracking	Stress-corrosion cracking of bridge cables, of landing gear on aircraft
Fatigue	Corrosion fatigue	Vibrating structures, such as aircraft wings, bridges, offshore platforms
Cavitations erosion	Cavitations corrosion	Ship propellers, pumps, turbine blades, fast fluid flow in pipes
Wear	Fretting corrosion	Ball bearings in chloride-contaminated oil
Radiation damage	Radiation corrosion	Increased susceptibility of stainless steels to dissolution or to stress-corrosion cracking

**Table 1.1**

### 2. Electrochemical Reactions

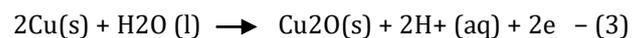
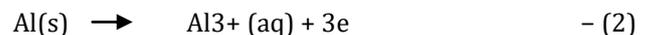
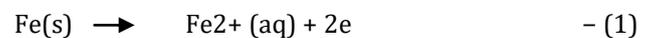
Corrosion is an electrochemical process, i.e., corrosion usually occurs not by direct chemical reaction of a metal with its environment but rather through the operation of coupled electrochemical half-cell reactions.

#### 2.1 Half-Cell Reactions

A half-cell reaction is one in which electrons appear on one side or another of the reaction as written. If electrons are products, then the half-cell reaction is an oxidation reaction. If electrons are reactants then the half-cell reaction is a reduction reaction.

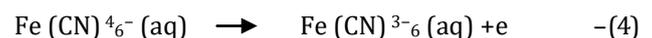
#### 2.2 Anodic Reactions

The loss of metal occurs as an anodic reaction. Examples are:



Where the notations (s), (aq), and (l) refer to the solid, aqueous, and liquid phases, respectively. Each of the above reactions in Equation (1), (2), and (3) is an anodic reaction because of the following:

1. A given species undergoes oxidation, i.e., there is an increase in its oxidation number.
2. There is a loss of electrons at the anodic site.



#### 2.3 Cathodic Reactions

1. A given species undergoes reduction, i.e., there is a decrease in its oxidation number.
2. There is a gain of electrons at the cathodic site (electrons are consumed by the reaction).

An example of a cathodic reaction is the reduction of two hydrogen ions at a surface to form one molecule of hydrogen gas:



Another common cathodic reaction is the reduction of dissolved oxygen to hydroxyl ions, a reduction reaction which occurs in neutral or basic solutions.



### 3. Units for Corrosion Rates

Common units for the corrosion current density include microamperes per square centimeter, mille amperes per square centimeter, and amperes per square meter. Various units have been used when the mass loss is the experimentally observed variable. These include grams per square centimeter per day and mdd (milligrams per square decimeter per day). Sometimes the corrosion rate is given as a uniform penetration rate. Units include ipy (inches per year), inches per month, and mpy (mils per year, where 1 mil = 0.001 in.). The units millimeters per year and micrometers per year have also been used. Collections of corrosion rate data are available for various metals and alloys in different environments. Stress-corrosion cracking, the geometrical constraints are the narrow dimensions of the crevice or the crack itself.

A compilation of corrosion rate data by NACE International provides a qualitative ranking of the severity of corrosion rates in terms of the units' mils per year. Which also lists corresponding electrochemical corrosion rates in microamperes per square centimeter calculated from Faraday's law for aluminum (a light metal), iron (a transition metal), and lead (a heavy metal).

The electrochemical corrosion rate depends, of course, on the atomic weight of the metal and the oxidation state of the metal ion, but in general, corrosion rates greater than about 100  $\mu\text{A}/\text{cm}^2$  are considered unacceptable.

Rigorous metric units, such as nanometers per second, have not held wide appeal to corrosion scientists or engineers.

### 4. Uniform vs. Localized Corrosion

There are two major types of corrosion namely uniform corrosion and localized corrosion. In uniform corrosion, the metal is attacked more or less evenly over its entire surface. No portions of the metal surface are attacked more preferentially than others, and the metal piece is thinned away by the process of corrosion until the piece eventually fails. Examples include the corrosion of zinc in hydrochloric acid and the atmospheric corrosion of iron or steel in aggressive outdoor environments.

In these cases, localized anodes and cathodes exist and operate as discussed earlier. However, the positions of these localized anodes and cathodes change with time and "dance" all over the metal surface so that the overall effect is that the metal is attacked uniformly. Each of these three forms of localized corrosion shares the common feature that there is a geometrical constraint on the system. In the case of pitting corrosion, the geometrical constraint is the cap of corrosion products above the propagating pit. For crevice corrosion and stress-corrosion cracking, the geometrical constraints are the narrow dimensions of the crevice or the crack itself.

### 5. Corrosion Types

The following eight forms of corrosion are mandatory at the time of vigilance audit or at regular inspection strategy as:

1. Uniform attack (or general corrosion)
2. Crevice corrosion
3. Pitting corrosion
4. Stress-corrosion cracking
5. Galvanic corrosion
6. Intergranular corrosion
7. Selective leaching (De-alloying)
8. Erosion corrosion

#### 5.1 Marine Paints

Vessels operate in seawater. So some surfaces of the vessel are exposed to seawater constantly, whereas some surfaces are not. But these surfaces are still surrounded by the sea. Therefore, marine paints must resist salt water as well as atmospheric corrosion.

#### 5.2 Types of Marine Paints

Three basic types of marine paints are in use. The types are as per paint composition.

1. General purpose marine paints: Alkyd resin based, Bitumen based and Gilsonite based. These paints have a protection life of about five to six months and cost relatively less. After the protection period, the vessel needs repainting.
2. Chlorinated rubber based: Good resistance to salt water and atmospheric corrosion. The protection life is about two years.
3. Epoxy resin based: This type is an expensive type, but the protection life is up to five years. There are also zinc-rich paints, which are still costlier, but the performance is very high.

#### 5.3 Paint Application on Ship

Depends on the area of the ship, it has been categorized as three main zones on outside while considering the point of inspection strategy as below:

1. Top, which does not dip in seawater. The maximum exposure to the seawater is the sprinkles due to winds and waves
2. Ship's side area, which is under seawater or above

seawater, depending on the vessel load, draft etc.

3. Bottom, which is always under seawater, during service, the paints suitable for the three areas are:

- ❖ Topside: Enamel resin based paints
- ❖ Ship's side: Chlorinated rubber based paints
- ❖ Bottom: Generally bitumen based paints and special treatment

#### 5.4 Indian standards for marine paints:

- ❖ IS 1419: Anti-fouling paint for ships' bottoms and hulls
- ❖ IS 1404: Anti-corrosive paint for ships' bottoms and hulls
- ❖ IS 2074: Red oxide-zinc chrome priming paint
- ❖ IS 6951: Paint for exterior finishing for ships
- ❖ IS 6714: Ready mixed paint, finishing, non-slip for deck

#### 6. CONCLUSION

1. If painting, use a good primer - not one that "sands easily" or contains talc. They absorb water and are soft - not a good thing under boat paint. The primer will not be glossy and will help you see what work still needs to be done. It will let you see little imperfections need a bit of filler. That's why I use primer. Technically you don't need it to get most paint to stick to epoxy so if you are painting a boat that is glassed and epoxy encapsulated you can skip the primer. For filler I like the 3M Marine Putty. Sets fast and sands nice.
2. Normally no clear coat of any kind is used. Too hard to repair and touch up. The only one I have seen for boats is the System 3 clear coat to go over their resistant at all. Cabinet guys like it since it dries water base linear (for more gloss). I would talk to them before I used it over another brand of paint. Do not use lacquer anywhere near a boat. It is not water really fast and levels nicely. They can get lots of shiny coats on in one day and be done.
3. The nice thing about painting lots of coats is that you get to practice. Only the last coat shows. The rest get sanded and all your learning happens with the primer and base coats of paint.
4. Sampling inspection plan shall be introduced to improve the coating methods and also for continuous monitoring.

#### REFERENCES

- [1] Sokol, E. Ul'yanin, E. Fel'dgandler, et al. (1989) Structure and Corrosion of Metals and Alloys. Metallurgiya, Moscow.
- [2] M. Barteri, F. Mancina, A. Tamba, R. Bruno (1987). Microstructural Study and Corrosion Performance of a Duplex and Super austenitic Steel in Sour Well Environment. Corrosion 43, 518-525.
- [3] J. Scully, R. Kelly (1986). "An Electrochemical Test for Detecting the Intergranular Corrosion Susceptibility of a Duplex Stainless Steel" Corrosion 42. 537-542.
- [4] B. Voronenko (1988). Corrosion-resistant Austenitic-ferritic Steels. Metal Science and Heat Treatment 22, 41-95.
- [5] V.Gadgil, S. Mandziej, B. Kolster (1988). Effect of Hydrogen of Behaviour of Materials. Proc. of the 4-th Int. Conf. on effect of hydrogen on the behaviour of materials, Wyoming, 375-386.
- [6] Yu. Romatovski, B. Voronenko, H. Chumalo, R. Melekhov (1992). Determining the Stress Corrosion Cracking Resistance of Cast Austenitic-ferritic Steel. Physicochemical Mechanics of Materials 1, 99-105.
- [7] L. Freiman, V. Makarov, I. Bryskin (1972) Potentiostatic Methods in Corrosion Investigations and Electrochemical Protection. Khimiya, Leningrad.
- [8] Vasilenko, R. Melekhov (1977) Stress Corrosion Cracking of Steels. Naukova Dumka, Kyiv.

**BIOGRAPHIES**

A.C. Mariappan, M.E, DPM, AMISLE, ASNT L-II., Assistant Professor, Department of Marine Engineering PSN College of Engineering & Technology, Tirunelveli, Tamilnadu. Also having specialization experience in NDT.



Dr. V. Janakiraman, B.E, M.E (CAD/CAM), PhD, Msc (Yoga), MISTE, FIE, MSAE, Professor, Department of Mechanical & Automation Engineering PSN College of Engineering & Technology, Tirunelveli, Tamilnadu. Also having 28 years of teaching experience in various colleges & university.



C. Kamaraj BE., (Marine) MSc, (Naval Arch.) MEO Class IV., Assistant Professor Department of Marine Engineering PSN College of Engineering & Technology, Tirunelveli, Tamilnadu. Also having 10 years of experience in structural designing of vessel, offshore structures.