"Critical Review paper of prevention of ship propeller due to salt formation Corrosion"

PRASHANT SINGH[1]; PARIWESH THAKARE[2]; DHANANJAY SAHU[3]

[1]PG SCHOLAR (DEPARTMENT OF MECHANICAL ENGINEERING, MATS University, RAIPUR);

[2]PG S SCHOLAR (DEPARTMENT OF MECHANICAL ENGINEERING, MATS University, RAIPUR);

[3]PG SCHOLAR (DEPARTMENT OF MECHANICAL ENGINEERING, MATS University, RAIPUR)

ABSTRACT

Paper discussed with the corrosion especially due to salt formation. Corrosion is the deterioration of materials by chemical interaction with their environment. The term corrosion is sometimes also applied to the degradation of plastics, concrete and wood, but generally refers to metals. The most widely used metal is iron (usually as steel). Ship propeller sinks into the sea water and in sea water, found the salt. Due to this salt formation in sea water, this affects the ship propeller. So, this review paper totally describes the salt formation corrosion and other corrosion and its preventions.

Keywords –ship propeller, salt formation corrosion.

1. INTRODUCTION

A propeller is a type of fan that transmits power by converting rotational motion into thrust. A pressure difference is produced between the forward and rear surfaces of the airfoil-shaped blade, and a fluid (such as air or water) is accelerated behind the blade. Propeller dynamics can be modelled by both Bernoulli's principle and Newton's third law. A marine propeller is sometimes colloquially known as a screw propeller or screw.

Fig. 1 ship propeller

2. SHIP/ MARINE CORROSION

Year upon year the cost of marine corrosion has increased until it is estimated today at 4 % of the Gross National Product. An enlightened approach to materials selection, protection and corrosion control is needed to reduce this burden of wasted materials, wasted energy and wasted money. These notes have been compiled by Members of the Marine Corrosion Forum to help marine designers, engineers, and equipment users, understand the causes of marine corrosion and the way in which protective systems and more resistant materials can be used to reduce or entirely eliminate sea water corrosion problems.

Many different types of destructive attack can occur to structures, ships and other equipment used in sea water service. The term 'aqueous corrosion' describes the majority of the most troublesome problems encountered in contact with sea water, but atmospheric corrosion of metals exposed on or near coastlines, and hot salt corrosion in engines operating at sea or taking in salt-laden air are equally problematical and like aqueous corrosion require a systematic approach to eliminate or manage them.

3. CORROSION BY SEA WATER

Corrosion by sea water, 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.
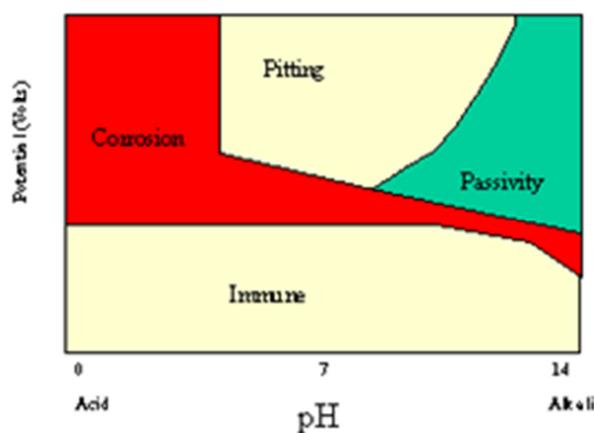
Fig. 2 Electrical potential – pH diagram

This typical diagram shows the regions where the metal will freely corrode; the region of passivation where stable oxide or other films form and the corrosion process is stifled; the region of pitting corrosion where the corrosion potential of the metal exceeds that of its oxide; and the region of immunity where the metal is normally fully safe to use. More resistant alloys mean less corrosion, metals like gold platinum and tantalum can resist virtually all corrosion, but for marine service the final choice will always be a compromise with cost.

Most corrosion resistant metals rely on an oxide film to provide protection against corrosion. If the oxide is tightly adherent, stable and self-healing, as on many stainless steels and titanium, then the metal will be highly resistant or immune to corrosion. If the film is loose, powdery, easily damaged and non self-repairing, such as rust on steel, then corrosion will continue unchecked. Even so, the most stable oxides may be attacked when aggressive concentrations of hydrochloric acid are formed in chloride environments.

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. The differential concentration of oxygen dissolved at the waterline 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 and are hidden start points of corrosion.

4.   MOST COMMON CORROSION MECHANISM

Many different corrosion mechanisms exist for Al alloys. The most common types are generally well understood. For each, the process is complex, incorporates many factors, and varies according to metal and specific operating conditions. Yet all still remain difficult to control, and represent a very serious threat to most industries. Once established, most corrosion problems will produce future years of operating difficulty and expense at varying levels of severity.

GALVANIC CORROSION

Galvanic corrosion occurs, when a metallic contact is made between a nobler and a less noble one (Wallen 1986; Dexter 1999; Bardal et al. 1993). A necessary condition is that there is also an electrolytic condition between the metals, so that a closed circuit is established. The area ratio between cathode and anode is very important. For instance, if the nobler cathodic metal has a large surface area and the less noble metal has a relatively small area, a large cathodic reaction must be balanced by a correspondingly large anodic reaction

concentrated in a small area resulting in a higher anodic reaction rate (Wallen 1986). This leads to a higher metal dissolution rate or corrosion rate. Therefore, the ratio of cathodic to anodic area should be kept as low as possible. Galvanic corrosion is one of the major practical corrosion problems of aluminium and aluminium alloys (Dexter 1999) since aluminium is thermodynamically more active than most of the other common structural materials and the passive oxide which protects aluminium may easily be broken down locally when the potential is raised due to contact with a nobler material. This is particularly the case when aluminium and its alloys are exposed in waters containing chlorides or other aggressive species such as SO4 (Bardal et al. 1993). The series of standard reduction potentials of various metals can be used to explain the risk of galvanic corrosion; however these potentials express thermodynamic properties, which do not take into account the kinetic aspects (Valen et al. 1989). Also, if the potential difference between two metals in a galvanic couple is too large, the more noble metal does not take part in corrosion process with its own ions. Thus, under this condition, the reduction potential of the more noble metal does not play any role. Therefore establishing a galvanic series for specific conditions becomes crucial.

PITTING

Pitting is a highly localized type of corrosion in the presence of aggressive chloride ions. Pits are initiated at weak sites in the oxide by chloride attack. Pits propagate according to the reactions
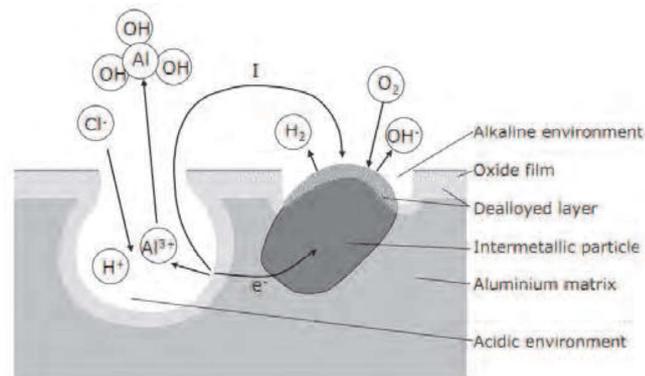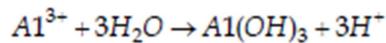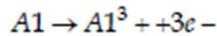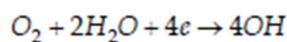
$$A1 \rightarrow A1^3 + +3e-$$

$$A1^{3+} + 3H_2O \rightarrow A1(OH)_3 + 3H^+$$

Fig.3. Pitting corrosion mechanism

$$2H^+ + 2e \rightarrow H_2$$

$$O_2 + 2H_2O + 4e \rightarrow 4OH$$
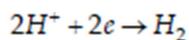
As a pit propagates the environment inside the pit (anode) changes. According to reaction 2 the pH will decrease. To balance the positive charge produced by reaction 1 and 2, chloride ions will migrate into the pit. The resulting HCl formation inside the pit causes accelerated pit propagation. The reduction reaction will cause local alkalinisation around cathodic particles. As previously mentioned aluminium oxide is not stable in such environment, and aluminium around the particles will dissolve (alkaline pits). The active aluminium component of the particles will also dissolve selectively, thereby enriching the particle surface with Fe and increasing its cathodic activity. Etching of the aluminium matrix around the particles may detach the particles from the surface, which may repassivate the alkaline pits. This may also reduce the driving force for the acidic pits causing repassivation of some in the long run. Figure 3 show pitting on an Al alloy.

Fig. 4. SEM images showing the pitting corrosion for propeller

INTERGRANULAR CORROSION

Intergranular corrosion (IGC) is the selective dissolution of the grain boundary zone, while the bulk grain is not attacked. IGC is also caused by microgalvanic cell action at the grain boundaries. The susceptibility to IGC is known to depend on the alloy composition and thermo mechanical processing. Grain boundaries are sites for precipitation and segregation, which makes them physically and chemically different from the matrix. Precipitation of e.g. noble particles at grain boundaries depletes the adjacent zone of these elements, and the depleted zone becomes electrochemically active. The opposite case is also possible; precipitation of active particles at grain boundaries would make the adjacent zone noble.

EXFOLIATION CORROSION

Exfoliation is yet another special form of intergranular corrosion that proceeds laterally from the sites of initiation along planes parallel to the surface, generally at grain boundaries, forming corrosion products that force metal away from the body of the material, giving rise to a layered appearance. Exfoliation is sometimes described as lamellar, layer, or stratified corrosion. In this type of corrosion, attack proceeds along selective subsurface paths parallel to the surface. It is possible to visually recognize this type of corrosion if the grain boundary attack is severe otherwise microstructure examination under a microscope is needed. In Al alloy, exfoliation corrosion occurred when the metal exposed to tropical marine environment. Also note the paint failures caused by corrosion of aluminium at the coating/aluminium interface. Exfoliation corrosion can be prevented by coatings, selecting a more exfoliation resistant aluminium alloy and using heat treatment to control precipitate distribution.

STRESS-CORROSION CRACKING (SCC)

Stress-corrosion cracking in aluminium alloys is characteristically intergranular. According to the electrochemical theory, this requires a condition along grain boundaries that makes them anodic to the rest of the microstructure so that corrosion propagates selectively along them. Intergranular (intercrystalline) corrosion is selective attack of grain boundaries or closely adjacent regions without appreciable attack of the grains themselves Aluminium alloys that contain appreciable amounts of soluble alloying elements, primarily copper, magnesium, silicon, and zinc, are susceptible to stress-corrosion cracking (SCC). An extensive failure analysis shows how many service failures occurred in the industry and what kind of alloys and stresses led to initiation and propagation of stress corrosion

cracks which caused these service failures. Alloys 7079-T6, 7075 -T6 and 2024 - T3 contributed to more than 90% of the service failures of all high-strength aluminium alloys. Aluminium and its alloys can fail by cracking along grain boundaries when simultaneously exposed to specific environments and stresses of sufficient magnitude. Well-known specific environments include water vapour, aqueous solutions, organic liquids and liquid metals. Stresses sufficient for crack initiation and crack growth can be far below the stresses required for gross yielding, especially in those alloy/environment combinations that are of

practical importance, e.g., high strength aluminium alloys in air. This phenomenon of environment-induced intergranular cracking is often called stress-corrosion cracking. With most service failures specific causes for initiation or propagation of stress corrosion cracks have been observed. The various causes usually belong to one of the following three classes: metallurgical, environmental and mechanical. This follows quite naturally from the old observation that for stress corrosion cracking to occur, three conditions have to be fulfilled: the alloy must be "susceptible" to SCC, the environment must be "damaging" and the stress (intensity) must be "sufficient".

CORROSION PROTECTION

Preventing corrosion requires the elimination or suppression of the chemical reactions described earlier. There are two principal methods, usually used in conjunction, cathodic protection and coatings.

CATHODIC PROTECTION

The objective with cathodic protection is to suppress the electrochemical reaction taking place at the anode. Under normal corrosive conditions, current flow from the anode results in a loss of metal at the anodic site with resultant protection of the metal at the cathodic site. By making the structure you wish to protect cathodic, protection can therefore be provided. There are two methods commonly used to do this:

SACRIFICIAL ANODES

When a metal corrodes it takes up its own electrical potential known as the corrosion potential with respect to a fixed reference. When two dissimilar metals are connected in seawater, the metal with the lowest potential will suffer the greatest corrosion (for more information, not included here, check information on the 'electrochemical series'). In simple terms, the affinity of a metal to return to its natural stable state (as described earlier) can be advantageously used in cathodic protection. Metals such as zinc and aluminium have a greater desire to return to their natural state than mild steel. The corrosion rate of mild steel can therefore be controlled by connecting it to for example, zinc, which

will then become the anode and corrode in preference to the steel. In this example, the zinc anode is referred to as a sacrificial anode because it is slowly consumed (corrodes) during the protection process. It should be noted that if the mild steel has a lower potential than other connecting metals, e.g. stainless steel heating coils in a cargo tank, under the right conditions, the mild steel will corrode preferentially.

IMPRESSED CURRENT SYSTEMS:

In the same way that coupling mild steel to zinc results in a flow of electrons (and hence protection) to the mild steel, the structure can also be made cathodic by using a direct current source. An auxiliary anode made from a non consumable material replaces the anode of the sacrificial system. In this example, the anode is permanent and is not consumed during the protection process. Another example of the use of cathodic protection is the galvanising of steel using a thin layer of metallic zinc. Generally, cathodic protection systems are used in conjunction with coating systems.

5.   Coatings

The effectiveness of coatings in preventing Corrosion depends upon many factors, for example, coating type, end use and operating environment. Many theories exist to explain the mechanics of corrosion protection by coatings.

INTACT COATINGS

Until about 30 years ago the predominant coatings protection theory was that coatings simply acted as a barrier to oxygen and water. Subsequent research has proven that oxygen and water, at a level sufficient to initiate the corrosion reaction, can indeed permeate through intact coatings. Current theories propose that water permeating through a coating to the steel surface can cause displacement of the coating from the steel allowing corrosion to occur. Low permeability and good 'wet adhesion' i.e. adhesion under immersion, are widely believed to be the single most important aspects of corrosion control by coatings.

ADHESION

For maximum coatings adhesion steel surfaces must be clean, dry and free of oil, rust, salts and other contaminants. Whilst increasing surface roughness results in a greater surface area and potentially increased coatings adhesion, this is not always the case. If the coating does not 'wet out' and penetrate into all of the pores/crevices on the steel surface there will be areas of coating not in direct

contact with the steel. In such cases more rapid oxygen and water passage through to steel will occur, resulting in corrosion and subsequent coating detachment.

Penetration of the coating into the surface or roughness profile can be improved by:

• reducing the relative surface tension of the coating

• reducing the coating viscosity

• modifying the coating solvent blend

• increasing coating curing time

• increasing coating application temperature

PERMEABILITY

Highly cross linked, chemically curing systems are likely to have relatively low permeability characteristics. Pigmentation can also have a significant effect. Coating permeability decreases as a function of increasing pigment volume in the film up to a critical pigment volume concentration (CPVC). Pigment levels above the CPVC will result in voids in the coating and permeability will increase. Pigment shape is also important with thin/flat (lamellar) pigment particles being preferred. The reason for this is that in solvent borne coatings, solvent evaporation causes the film to shrink and these results in the alignment of these lamellar pigments parallel to the surface, restricting the passage of oxygen and water. The most effective lamellar pigments are leafing aluminium flake and micaceous iron oxide. Film thickness can also affect coatings permeability. In general, thicker films delay (but do not stop) the passage of oxygen and water to the steel surface. This is because in all coating films microscopic defects are present which can penetrate to the steel surface and ct as conduits for oxygen and moisture. High film thickness (>400 um dft) can therefore offer a high degree of corrosion protection but this would best be achieved in multi-coat systems rather than in a single coat. High film thickness single coat (or some two coat specifications) also have disadvantages as, subject to coating type and formulation, solvent entrapment may occur which can lead to blistering.

Equally, high film thickness may also be a problem on complex structures e.g. ballast tanks and may result in cracking of the coating and subsequent corrosion.

NON-INTACT (DAMAGED) COATINGS

Coatings in service e.g. cargo hold coatings, deck coatings and hull coatings will be subjected to mechanical damage. Maintaining corrosion protection can therefore best be achieved by using coatings which offer both abrasion resistance and corrosion protection

It is also recommended that coatings have good 'undercutting' resistance i.e. resistance to under film corrosion creep at damaged areas and have good resistance to the alkaline hydroxyl ions produced during the corrosion process. Other mechanisms used to prevent corrosion in non-immersed, above water areas include:

• the use of anticorrosive pigments such as zinc phosphate. This pigment is slightly soluble and can form a corrosion inhibiting molecular layer at the steel surface.

• the use of metallic zinc as a sacrificial pigment, in essence the development of an "in situ" cathodic protection system.

With corrosion potentially costing the marine industry billions of dollars per year, effective corrosion control measures, including the correct choice of coating system, should be very carefully considered.

6.   CONCLUSIONS

It is concluded that this review paper describes prevention of ship propeller due to salt formation corrosion, which is very interested. This paper reviewed all the research paper and its references. In future, we may use this paper for the purpose of our thesis report.

REFERENCES

[1] Pirhady Tavandashti, N.; Sanjabi, S. & Shahrabi, T. (2009). Corrosion protection evaluation of silica/epoxy hybrid nanocomposite coatings to AA2024. *Progress in Organic Coatings*. Vol. 65 (October 2008), pp. 182–186, ISSN 0300-9440.

[2] Touir, R. Cenoui, M., El Bakri, M. & Ebn Touhami, M. (2008). Sodium gluconate as corrosion and scale inhibitor of ordinary steel in simulated cooling water. *Corrosion Science*. Vol 50 (June 2008) pp.1530-1537. ISSN. 0010-938X.

[3] Yao, S., Jianga, X., Zhoua, L., Lva, Y. & Hub, X. (2007). Corrosion inhibition of iron in 20% hydrochloric acid by 1,4/1,6-bis(α-octylpyridinium)butane/hexane dibromide. *Materials Chemistry and Physics*, Vol. 104 (August 2007), pp.301-305. ISSN: 0254-0584

[4] Bajat, J.B.; Miškovic´-Stankovic, V.B.; Kacˇarevic´-Popovic´, Z. (2008). Corrosion stability of epoxy coatings on aluminum pretreated by vinyltriethoxysilane. *Corrosion Science*. Vol. 50 (April 2008), pp. 2078–2084, ISSN 0010-938X.

[5] Bereket, G.; Hur, E. & Sahin, Y. (2005). Electrodeposition of Polyaniline, Poly(2-iodoaniline), and Poly(aniline-co-2-iodoaniline) on Steel Surfaces and Corrosion Protection of Steel. *Applied Surface Science*. Vol. 252, (December 2005), pp. 1233–1244, ISSN: 0169-4332.