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ABOUT CORROSION IN MARINE ENVIRONMENTS

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ABSTRACT

The cost of marine corrosion has increased year upon year. There are many different types of destructions that can occur to ships, structures and other equipment used in sea water service. Corrosion resistance in natural seawater is better than that in laboratory prepared salt water having the same total salinity. Corrosion affects all areas of industry and does not spare installations, industrial sites, machinery or any other production equipment. But it is in the open sea that it appears even more tenacious, and it is natural given the permanent presence of moisture and salt. Corrosion that is not treated in a timely manner can have fatal consequences for the ship itself, the crew and, where appropriate, passengers and cargo.

Keywords: ships, corrosion, protection, procedure

1. INTRODUCTION

The corrosion of metals is a process of returning to their original state, that is to say to the state they had before the implementation of the metallurgical processes and in particular the refining operations which make the metals unstable.

The corrosion of a metal thus acts by oxidation and degradation under the action of stresses in a so-called corrosive medium. As regards the constitution of ships, the metals used are mainly steels, aluminium and copper, the corrosive environment considered being the marine environment: sea water and saline air.

This environment is the ideal environment for the creation and development of corrosion given the physical and chemical properties specific to seawater.

These include:

- the presence of several dissolved gases, in particular dioxygen, which is one of the active ingredients of corrosion
- very good electrical conductivity
- the salt content
- the concentration of bacteria
- the pH which is between 7.5 (in hot water) and 8.5 (in cold water)

There are two types of corrosion: dry and aqueous. The one that concerns the marine world is aqueous corrosion. This corrosion, of an electrochemical nature, is characterized by the displacement of electrons without any external source. In the marine environment we speak of marine corrosion.

Corrosion being a function of the operating environment, design and materials used, understanding of the mechanisms of corrosion will enable more appropriate geometry and detail in design and ships fabrication.

2. THE TYPES OF CORROSION

Several classifications are possible to list the types of corrosion that ships face. In this article, we propose to divide the types of corrosion by considering the electrolyte fluid in motion or motionless. On board ships, we may therefore be faced with the following phenomena.

2.1. FLUID IN MOTION

2.1.1.Corrosion by cavitation

Cavitation occurs in a relatively turbulent flow. This is the formation of bubbles following a local decrease in pressure below that of saturated steam. When the pressure of the fluid around these bubbles increases above a critical value, they implode very quickly while releasing considerable energy, thereby altering the surrounding metal surfaces. When this phenomenon is repeated regularly in the same place, this causes material fatigue and a progressive deterioration of the surface protections resulting in a loss of localized mass.

Cavitation corrosion is often found on ship propeller blades, pump impellers and turbine blades. This loss of mass then causes an imbalance of the rotors, thus generating noise, vibrations and performance losses.

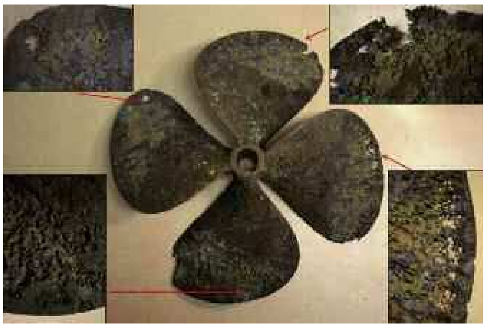

Fig.1. Example of a propeller corroded by cavitation

2.1.2.Corrosion by abrasion

This phenomenon occurs essentially when the fluid is charged with suspended particles thus rubbing surfaces such as the walls of the pump bodies or the inner linings of the circuits. There is then an alteration and, eventually, a deterioration of the protective films of the metal which, once exposed, sees the aqueous corrosion processes start.

2.1.3.Erosion corrosion

This type of corrosion is generated by:

- the repeated shocks by drops or projected particles (eg sea bunches, spray)
- the turbulences of a fluid generated by a surface defect (eg coarse finish of a protective inner lining of a circuit). A progressive loss of a part of the protective coating is then observed until its complete disappearance.

2.2. STAGNANT FLUID

2.2.1.Galvanic corrosion

This corrosion appears in the presence of metals of different nature bathed in an electrolyte, in this case the marine environment with respect to ships. Let us recall that metals are classified by their corrosion potential for a given electrolyte. Metals with high potential are said to be noble while those with low potential are called basic. For seawater at 20°C, the corrosion potential of titanium is of -0.05 volts, that of stainless steel is -0.5 volts, and that of zinc is - 1.05 volt. As a result, two metals of different corrosion potentials generate a potential difference which leads to the flow of an electric current responsible for the corrosion of the least noble material.

The main factors favouring galvanic corrosion induced by the neck of two metals are essentially:

- the nature of the metals: composition, value of potential difference, impurity level, possible presence of a protection
- the geometric parameters: relative surfaces between the anode and cathode zones, the distance between the two metals
- the local properties of seawater: pH, temperature, environment (open sea, delta, outlet, ...), turbulence, agitation.

2.2.2.Pitting corrosion

It affects passive metals and mainly concerns steels, aluminium and copper. After losing its protection due, for example, to punching, the corrosion process is established by a rapid localized perforation of the metal in a cavity of a few micrometers.

2.2.3.Crevice corrosion

Also called cavernous, this type of corrosion is found in the slots and interstices in which the fluid stagnates without being able to renew itself resulting into a rapid consumption of oxygen and ion concentration. In the case of alloys such as stainless steel and nickel alloy, this oxygen deficiency prevents repair of the passive protective film and the material then active.

We can find cavernous corrosion:

- on the range of a joint
- on a screw thread or an internal thread
- between two riveted plates

The hull of a ship which has interstitial disorders will be advantageous to crevice corrosion if it is docked at the wharf on the open sea. Indeed, once at sea, these interstices are no longer considered as of confined environments due to the fluid renewal inside due to vessel speed.

2.2.4.Corrosion by marine microorganisms

The chemical composition of sea water allows for a very prolific biological activity. Some microorganisms such as bacteria and algae as well as some crustaceans tend to colonize immersed metals without protection very quickly. This colonization constitutes so-called fouling, generating physic-chemical reactions favourable to an acceleration of the corrosion process. Hull and seawater circuits are mainly concerned with this phenomenon.

2.2.5.Corrosion under stress

This corrosion results from the association between mechanical stresses and the fact of being in a corrosive medium, it being understood that the application of these same stresses on a metal would have had less negative effects if it had been placed outside of this corrosive medium.

These mechanical constraints are of residual orders (welding, bending, ...), thermal (expansion, ...) or in relation to a functional necessity (cables, beams, ...). The symptoms appear mainly in the form of cracks. Regular periodic inspections of ships include, among other things, the detection of this type of damage, which, if not taken into account, may contribute to the embrittlement of the structure which renders the ship vulnerable in heavy weather.

Fig.2. Example of a ship zone corroded under stress

3. HOW TO COMBAT THESE CORROSIONS

The assessment and implementation of appropriate vessel protection against corrosion at the time of its construction is essential, taking into account, inter alia, the costs of corrective actions during operation, such as drying, duration of the technical stop, the refection of the coatings (hull, bunkers, empty mesh, ...) and means of access (nacelles, scaffolding, ...).

It is estimated that repairs to paint coatings are approximately ten times more expensive than construction operations. The installation of the protections must therefore be carried out with rigor and one must be fully aware of the various corrosion phenomena involved.

Prevention of marine corrosion key factors are materials selection, design, construction, operations and way of maintenance.

There are several corrosion protection systems that can be divided into three categories: cathodic protection, protective coatings and so-called geometric protection.

3.1. CATHODICAL PROTECTION

This type of protection is based on lowering the corrosion potential of the metal to be protected by placing anodes. On ships we find two types of cathodic protection.

3.1.1.The sacrificial anodes

The purpose is to distribute such anodes in order to create a galvanic current. Most often of zinc or aluminium, these anodes undergo corrosion alone and thus preserve the noblest metals. They are placed in equipment using sea water (circuits, exchangers, bal-lasts, ...), on the hull and the immerged appendages of the ship.

Fig.3. Example of sacrificial anodes on a ship hull, Source: wrsmarine.nl

To be truly effective, certain precautions must be taken:

- the nature of the anode must be such that its potential is sufficiently negative to ensure sufficient polarization and an adequate potential difference

- the distribution and weight of the anodes must be calculated as closely as possible

- the contact surface must be nominal so that the anodes are properly connected to the structure to ensure good conductivity; Their fixing and their shape are then chosen accordingly

- a periodic wear monitoring is required to ensure timely replacement

- their location and the type of fastening are studied so that they can be changed quickly and with little disassembly; The immersed sacrificial anodes are preferably screwed rather than welded.

The sacrificial anodes on the hulls of ships have nevertheless the main inconvenience of creating a resistance to the advancement thus generating an overconsumption of fuel. These will have to be replaced fairly frequently.

3.1.2.Cathodic protection by imposition of current

This protection is provided by a DC generator from which the negative pole is connected to the equipment to be protected and the positive pole to the anode.

If this system can represent a significant cost to the installation, it becomes profitable during the operation since it does not require much energy.

The evolution of hydrogen resulting from the electrochemical reaction requires that this type of protection is not used in confined media.

3.2. PROTECTIVE COATINGS

These are surface coatings of three types:

- metallic materials to protect in particular steels. For this purpose it is use chromium, copper or zinc

- polymers using thermoplastic, rubber or thermosetting

- by successive paints: a primary layer called anti-corrosion coating, secondary layers for sealing and perfecting the surface state, and then a finishing layer ending the sealing power and, if necessary, giving an aesthetic touch. The application of paints requires the manufacturer's instructions to be observed in order to guarantee an effective hold over time. The respect of the hygrometric conditions and the preparation of the surface are paramount. It should be noted that over 90% of the damage to the hull covers of ships is due to poor application.

These three types of coatings are hard coatings as opposed to so-called soft coatings which are used for short-term applications such as storage of spare parts or moving panel axes (doors, hatches, etc.).

In most cases, these soft coatings are special greases. If the preparation of the surface is simple and rapid, the disadvantages are numerous: frequent re-applications, flammable product, sensitivity to water and restrictive removal operation.

3.3. GEOMETRIC PROTECTION

This protection consists in designing the parts and the mechanical assemblies in such a way as to limit the risks of corrosion.

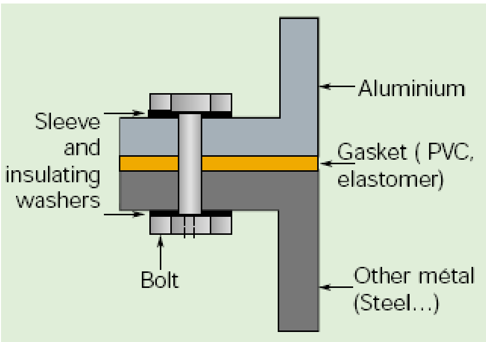

Fig.4. Insulation of aluminium

For example, it is advisable to:

- provide collector curves for non-turbulent fluid flow. Turbulence is partly responsible for cavitation and erosion corrosion

- design containers and tanks that do not promote stagnation of water.

For aluminium and its alloys, the problems are best addressed by examining the typical modes of corrosion. To prevent corrosion, geometry and detail considerations rather than to provide protection are similar to metal choices alternative and answer the needs to accommodate corrosion mechanisms.

By geometric arrangements that can exclude moisture traps and that will avoid crevices a good design will avoid corrosion.

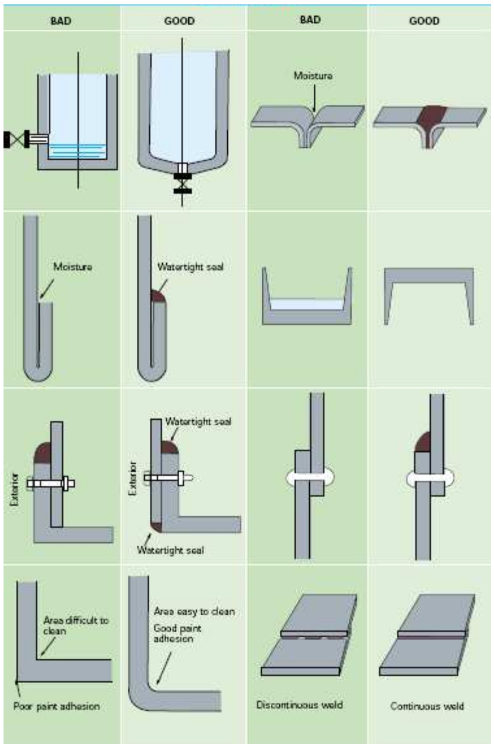

Fig.5. Effect of design arrangements

4. CONCLUDING REMARKS

The multi-decadal experience of marine applications of aluminium shows that the resistance to corrosion is remarkable.

However:

- some aluminium alloying families are contraindicated for this type of application,

- the transformation ranges must be adapted to avoid accidental sensitization of the 5000 aluminium alloy to structural corrosion (intercrystalline corrosion, leaf corrosion or corrosion under stress).

Finally, the temperature operating conditions must also be checked so as not to exceed certain thresholds and holding times. The material state has the advantage of being subjected to a mandatory control of the susceptibility to the leafy corrosion.

Since the risks of corrosion on a ship are relatively high, it is essential to ensure that corrosion cannot take place. In addition to the preventive actions given above, there are simple principles to be applied in order to limit an eventual proliferation of corrosion if it should appear:

- ensure a proper ventilation of the premises by ensuring adequate hygrometry and flow
- regularly rinse with fresh water the superstructures exposed to the bad weather (waves, sea spray, saline air, ...)
- evacuate stagnant water, especially in holds, bottoms and under gratings
- identify and, if possible, deal without delay with disorders on protective coatings
- ensure a perfect sealing of the technical cabinets and cabinets and, in particular, electrical
- track down all corners of the ship to try to detect corrosion initiation (blisters, blistering, cracks, rust, ...)
- histories of corrosions discovered as they were measure
- comply imperatively with the manufacturers' recommendations for the application of paints

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