CORROSION PROTECTION IN SHIPBUILDING

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ABSTRACT

In the ship building process and its operational period, the ship is exposed to various chemical influences of the environment that cause different corrosion damages. Severe structural material damage caused by corrosion can affect both the safety and overall life of the ship. To slowdown or eliminate the corrosion process on the ships they have to be protected by various measures and technological procedures.

The paper presents the technological processes of corrosion [1]protection, starting from structural and technological measures, application of protective coatings, the use of corrosion resistant materials, cathodic protection and the employment of inhibitors. Consequently, the corrosion protection in shipbuilding is an important technological process, which may ultimately and significantly affect not only ship's service period, but also the price of the ship building and maintenance costs.

Keywords: shipbuilding, ship corrosion, corrosion protection process

1 INTRODUCTION

Methods of corrosion protection are based on the theory of corrosion processes. Alterations of the material properties and external environmental characteristics are the factors which can affect the slowing down or stopping of the corrosion process. Corrosion protection in the shipbuilding industry is an important technological process devised to protect the ship from corrosion effects. Figure 1. shows storage area of plates, profiles and flats in a shipyard exposed to severe environmental conditions. This paper describes the technological operations and methods of corrosion protection, starting from the application of paint in the workshop process, cathodic protection, protection of the inhibitors, as well as the use of corrosion resistant materials to the construction of technological solutions.

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Figure 1: Storage area of plates, profiles and flats in a shipyard

2 PROTECTION COATING IN SHIPBUILDING

2.1 Preparation of surface

Surface preparation is a demanding technological operation (figure 2. shows ballast tanks sections) in the development of the ship's hull from primary surface preparation of plates, profiles, and flats performed in the automatic installation (clean steel surface under the contract is defined as surface condition 2.5 according to ISO 8501-1, 1988). It also includes a basic workshop procedure called coating. Shop primer in the film thickness 15-25 μm is used for the protection of steel in the process of ship construction. However, mandatory control of the thickness of the coatings for greater thickness may adversely affect the cutting speed and quality of steel, as well as the occurrence of errors in welding [1]. Secondary surface preparation is carried out in the halls for sand blasting and painting, whereby dirt and salt should be removed from the surface of the section, rendering it and sandblasting according to standard ISO 8501-1 (to remove any defects arising in the course of the volume section). Prior to performing a secondary surface preparation, preparing the steel surface, figure 3. (referred to as ballast space) is done, steel preparation according to ISO 8501-3 grade P2 that covers repairs to finishing damage in the section. This technological operation implies extra work in welding and grinding and represents the pre-assembly sockets.

Figure 2: Ballast sections

Figure 3: Ballast section steel preparation

2.2 Temporary protection workshop

The first stage of corrosion protection in the shipbuilding industry consists of the workshop coating (shop primer) on the plating profile and flats in a thin film, about of 15 to 25µm thick, as excessive film thickness may negatively affect the quality of welding (the occurrence of porosity) and cutting steel. Shop primer represents fast-drying coatings which are used for temporary protection of steel in the workshop during ship construction and application of the final coating system. Temporary corrosion protection is performed in the workshop of processing in automated plant starting from drying sheets, shot blasting and coating according to the standard ISO 8501-1. Workshop coatings used are zinc silicate and epoxy iron oxide shop primer. Epoxy iron oxide is applied to obtain a greater thickness, demanding more paint, consequently resulting in higher coats and increased losses [2]. Today in most shipyards zinc silicate is used as shop primer (with a share of 25-35 % zinc), which provides a better quality welding and reduced occurrence of undesirable zinc salts (a compound hardly soluble in water and difficult to clean from the surface),

Shop primer must meet the following requirements:

- must be suitable for automated staining procedures,
- have the shortest drying time (3 to 5 minutes),
- resistance to high temperatures,
- must not release toxic gases during welding and cutting,
- must not negatively affect the welding process,
- compatibility with other coating systems,
- must not affect the mechanical properties of welded joints.

2.3 Terms of coating

The technological process of preparing the surface hull is done by destroying the metal surface in a stream of air under high pressure and abrasive sandblasting or shot blasting to ISO 8.501. Surface preparation standards include several criteria, rules and guidelines for the process of preparing hull metal surfaces. Surface conditions of steel structures are divided into four stages:

- steel surfaces covered with mill scale and little corrosion,
- steel surfaces, which have begun to corrode and from which mill scale has started to peel,
- steel surface exhibiting particles of rust or poorly applied fretting mill scale with the first visible sings of pitting,
- steel surface that is visibly corroded and affected by pitting.

The process of preparing metal surfaces done by means of abrasives. Abrasives are different types of materials suitable for the particular grit surface preparation, where the abrasive particles using compressed air are applied to the surface which is to be cleaned. The quality of the preparation of steel surfaces is shown by the following levels of ISO 8501 [3]:

- "Sa 2": a thorough cleaning. The surface must be clean with no marking of oil, grease, or dirt visible to the naked eye, and almost completely free of rust, old paint and dirt. Any remaining residues should firmly adhere.
- "Sa 2.5": a very thorough cleaning. The surface must be clean with no visible traces of oil, grease and dirt, and almost completely free of mill scale, rust, paint coatings and strange impurities, so the remaining tracks may seem like mild spots or shadows.
- "Sa 3": by abrasive blasting, all impurities are removed from the steel. The surface must be clean with no visible traces of oil, grease or dirt and completely

free of mill scale, rust, paint coatings and strange impurities. The surface must have a uniform metallic look.

- "St 3": manual removal of rust by hand or mechanical tools for cleaning. The surface has to be seen without a magnifying glass as free from traces of oil, grease and dirt, without further residues of mill scale, rust, paint coatings, or strange pollution, so it shows a mild metallic sheen.

Abrasives used for cleaning metal surfaces can be divided into two main groups: metal and mineral abrasives. Basic characteristics of the abrasive are its hardness, size and shape. For manual removal of rust, the following tools for cleaning are used: a scraper, a hammer to remove the rust, a gun fitted with a needle, a steel brush (manually or mechanically driven), and grinding wheels for grinding. For manual cleaning, as a rule , the degree of surface preparation St 3 should be achieved.

2.4 Methods of applying coatings

The technological process of corrosion protection uses different methods of applying coatings (figure 4. illustrates stripe coating method) by brush, roller or spraying (air or airless), where the selection of the procedure affects the speed and quality of works.

Figure 4: Stripe coating section

- Paint brush is usually used for the procedure "touch-up" in the protection of areas such as joints, transitions, edges, welds and other rough surfaces and pitting. In these areas, dye penetration is achieved by applying the proper brushes: it can not be achieved by any other method.
- Paint roller is rarely used because of its defects, formation of small bumpy layers, usually with small gaps and holes, which is why penetration is very weak and it is difficult to achieve high-quality layer thickness.
- Applying a coating by spraying is based on dispersing the paint in the form of tiny droplets that settle on the working parts. Airless spraying is a method that is most common in the shipbuilding industry because it enables rapid application of paint onto large surface, high impact, the possibility of applying thicker layers, as well as good penetration.

3 CATHODIC PROTECTION

Cathodic protection of ship is an integral part of every ship on its underwater part and the protection of coatings is the most common method of corrosion protection employed in shipbuilding. The primary task of cathodic protection is an electrochemical method of protecting metals from corrosion effects and is effective only if there is a conductive medium between the anode and the structure that protects it [2]. There are two main types of cathodic protection:

- cathodic protection by means of a sacrificial anode
- impressed current cathodic protection system

3.1 Cathodic protection by means of a sacrificial anode

When two metals come in contact with each other in the presence of water, the less precious metal will have a lower potential than the precious one. This potential difference between metals in contact generates an electric current between them. The current flows from the precious metal (the cathode) to the less precious one (the anode). A continuous flow of electricity to the less precious metal causes the release of more positive ions, which dissolve in water. This leads to the slow dissolution of less precious metals in water. This metal dissolution is called anodic reaction, while the metal that dissolves is called the anode. Sacrificial anodes consists of pieces of metal that have a lower potential in sea water than the metal of the hull being protected.

Anodes are made from non-precious materials and tend to corrode more easily than iron. Sacrificial anode is typically made from zinc, aluminium, or in rare cases, magnesium. Magnesium anodes were once used much more frequently than today, but were eliminated because magnesium produces a lot of hydrogen in the process, thereby adversely affecting the natural environment. Today the most widely used material for sacrificial anodes of zinc, welded to different places on the ship's plating (see figure 5.). The anode has a lower potential compared to the steel plating, so that they "absorb power" beyond the exposed part of the plating, thereby generating a circuit between the zinc anode and the parts of ships made from copper or other precious metal alloys (e.g. the marine propeller). In this way the zinc is consumed, and the steel hull is simultaneously protected. When the zinc anode wears out, the circuit is established between the next less precious metal, resulting in its dissolution. For the protection of steel in the sea about 140 mA/m^2 , colored steel 10-15 Ma/m^2. is required. Therefore the cathodic protection is regularly used in combination with protective coatings. If the layer of paint in the underwater part of the hull is damaged, it enables a flow of electricity between sea water and metal. The more serious the damage, the higher the zinc anode wear rate will be. When installing the anode it is important to achieve a good weld between the hull and the anode, and the anodes must not be coated with paint. Anodes are usually rectangular and flat, adapted to the particular part of the hull or the equipment requiring protection.

Figure 5: Zinc plating anodes aboard ship

Cathodic protection systems using sacrificial anodes are very flexible, because the small anodes can be arranged so that they can ensure an effective protection of the entire ship structure. The only drawback in the application of sacrificial anodes is that it requires frequent welding onto the hull, which can result in both external and internal traces of damage to the external plating, also necessitating repeated repair works. The advantages of cathodic protection anodes could be summed up as follows:

- between two overhauls the ship does not require particular maintenance,
- low cost,
- the availability throughout the world.

The disadvantages are:

- limited duration of 1-5 years, which is difficult to predict,
- damage to the outer plating caused by friction against flatting objects in the sea, which can greatly accelerate anode wear.

3.2 Induced current cathodic protection system

In induced current cathodic protection system (figure 6.), a flow of electric current is generated from an external source, protecting the parts of the hull which are in contact with sea water, thereby causing a cathode reaction which, in turn, protects the steel from corrosion. The hull is usually connected via amplifiers to the negative half of the power source, while the positive pole is connected to the anode and due to possible damages, built into the bottom shell. Anodes are made from precious metals such as platinum, conductive polyplastics, etc. The area around the set of hull anodes should be protected by special coatings. Currents and voltages of the cathode protection vary depending on the size of the ship, the damaged surface of the ship, speed, sea water salinity, and the number and position of the anodes. The advantages of this system consist in the minimum maintenance requirements, high reliability, and continuous control of protection parameters. The initial high cost of this protection, as compared to the method using sacrificial anodes, can be returned in six years. The disadvantages include the following: the possibility of erroneous connection of the system, potentially causing rapid and intense corrosion damage to the hull, while excessive protection may damage the protective coatings [4].

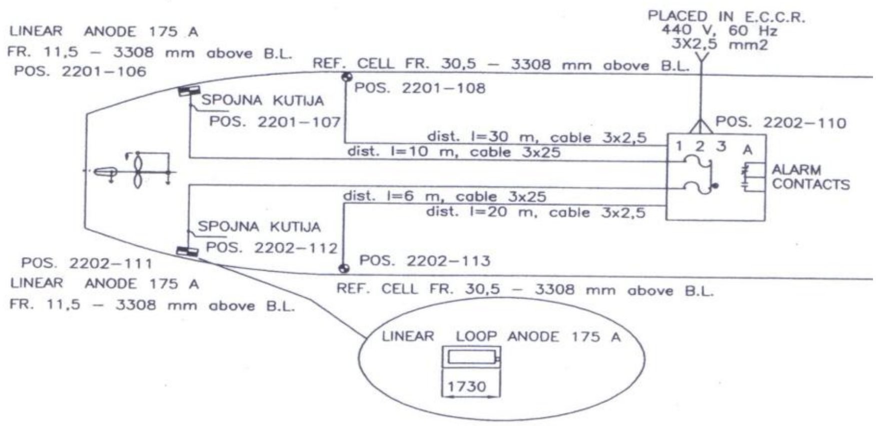

Figure 6: Scheme of the applied cathodic protection current to 46,000 dwt chemical tanker

4 APPLICABILITY OF INHIBITORS

Corrosion inhibitors are substances defined as inorganic or organic in origin, which in a very low concentrations assist in reducing the corrosion rate to technologically acceptable levels. According to the mode of action, inhibitors are classified as anodic, cathodic and mixed (anode-cathode). Due to the specific action, such as uniformly filling the space and creating a protective to the metal surface, thereby preventing its contact with the environment and the media, inhibitors are applied for the protection of marine structures in inaccessible places such as the keel, rudder etc. Inhibitors evaporate and are adsorbed on all metal surfaces, with the inhibited layer being continuously renewed, so that no regeneration of the protective system during its life is necessary. Inhibitors are used in enclosed spaces on board which are exposed to aggressive atmospheric influence, sea water containing a high level of chloride, high humidity and frequent changes in temperature, all of which contributing to an increased corrosion of the hull. In these conditions, poorly applied protection coatings due to inaccessibility do not meet the necessary requirements of durability, thereby rendering inhibitors the most suitable solution in the protection of such areas. In the Croatian shipyards inhibitors are used for the protection of the interior parts of the rudder, where a simple application offers a uniform quality of protection of the structure. Evaporating inhibitors are blown into the rudder through the bores which are subsequently closed.

5 USE OF CORROSION RESISTANT MATERIALS

In the shipbuilding industry, in addition to standard shipbuilding steel and high strength steels, stainless steels resistant to corrosion are being increasingly used [4]. Their use is most frequent in the area of cargo tanks AISI 316 L (communication in cargo tanks and wells for the cargo unloading system), as well as individual pipelines located on the main board (figure 7.). Corrosion resistant steel is a structural material with a high corrosion resistance, but in certain circumstances it may often become prone to, potentially very dangerous, accelerated local corrosion damages (e.g. pitting, contact, selective, and crevice corrosion). These phenomena typically occur in places of connections, joints, or weld, where the prescribed welding technology and procedures should be strictly adhered to.

Figure 7: Cargo pipes on the main deck

6 CONSTRUCTION TECHNOLOGICAL MEASURES

A particular challenge for the designer is creating quality classification drafts that could affect the ship safety and its durability in service. It is therefore necessary and important that the designers**,** ship-builders, and technologists should closely collaborate, with a view to adjusting the construction and prescribing the required technology, thereby preventing any future occurrence of corrosion processes that could prove potentially damaging to the life of the ship.

7 DAMAGES DURING CONSTRUCTION OF THE SHIP

The cost of the ship production can be significantly affected by a higher accuracy in the construction of the hull sections, an adequate organisation of technological processes, corrosion protection, as well as by a close monitoring of the construction of particular section units (figure 8.). The control of sizes and shapes in shipbuilding industry is primarily aimed at ensuring the accuracy of sections, which will simplify and facilitate the installation of the ship, as well as reduce the amount of subsequent work (correction works in steel and additional anticorrosive works). This will also result, during the mounting of the hull, in the increase of its quality, a reduction of any amount of additional work, a reduction of overall production costs, as well as a substantially shorter production cycle [4].

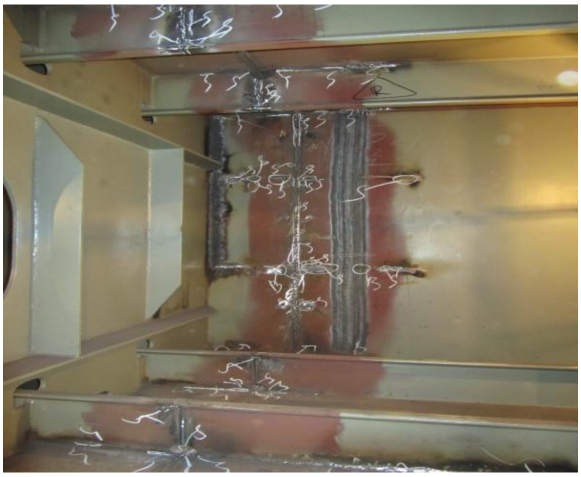

Figure 8: Erection joint between two sections

8 CONCLUSION

The technological process of corrosion protection in the manufacturing process of the ship construction is an extremely important one because a well-designed corrosion protection is a prerequisite for a long life of the ship and its service. The ship is exposed to highly aggressive environments, particularly sea water. By a proper design of the structure, varied design solutions and manufacture technologies, and quality of work regarding corrosion protection, the quality of the ship can be increased and its life significantly extended.

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