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INTEGRATED CORROSION PROTECTION SYSTEM FOR SHIP STRUCTURES

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ABSTRACT

Corrosion combined with fouling growth can interfere with the operation of submerged equipment, impose increased loading stresses and accelerate deterioration of marine structures, and adversely affect the performance of ships by increasing hydrodynamic drag, which necessitates the use of more power and fuel to move the ship through the water. The protection of the submerged portions of a ship's hull seems to have been long acknowledged and practiced but corrosion related failure of ship components continue to occur giving economical loss to ship owners. An enlightened approach to materials selection, protection and corrosion control is needed to minimize the risk of failures or major renewals of hull structures during the ship's expected life span. Further, Proper and cost effective corrosion protection measures are necessary to maintain the asset value of the vessel with a special emphasis on the means and methods now being adopted in international regulatory regimes to contain it. This paper addresses the causes of corrosion in ship and the way in which corrosion can be reduced or entirely eliminated in a ship by integrating both technical and non technical methods of corrosion control.

Keywords : Corrosion, Corrosion Control, Corrosion Management, Marine Corrosion, Ship,

1. INTRODUCTION

Effective corrosion control in hull structure is one of the most important features for the shipping industry to ensure reliability and minimise risk and major removal of hull structure. The problem of hull corrosion has become a great concern for ship owners as they have increasingly recognised the need to protect their investment and demonstrate a commitment to safeguard the structural integrity of ships. Corrosion can be mitigated primarily by two methods. One method is technical approach which includes coating, cathodic protection and inhibitors etc [1]. The other method is a managerial approach (CM) which is less technical and more managerial and this has not been a major focus of attention for ship owners for many years.

To ensure continued integrity at minimum cost, corrosion has to be actively managed from design stage to the end of ship life. Corrosion management is a system approach involving all aspects of human factors to reduce the risk of corrosion failure. The primary objective of this paper is to provide an overview on different forms of corrosion in ship and how to prevent corrosion and enable ship owners to protect their investment and safeguard the structural integrity of ships.

2. TYPES OF CORROSION IN SHIPS

Corrosion of ships is the result of several different types of corrosion. The most common one is general corrosion or wall thinning of the hull due to seawater attack. Studies have shown that the rate of this form of corrosion is approximately 0.1 mm (4 mils) per year. At this corrosion rate, it would take approximately 62 years to have a thickness reduction of 6.4 mm. Because of this slow rate, general corrosion is normally not a consideration in a ship's design life.

Galvanic corrosion occurs between two metals with dissimilar electrochemical potentials. In this form of corrosion, one of the metals is more electrochemically active and corrodes, while the second metal is protected by the corroding metal [2]. The metals can even be of the same material if the electrochemical potential of one of the materials has been changed due to stresses or differential aeration. Previous studies have indicated that most hull corrosion is galvanic in nature. Salt spray and atmospheric corrosion can severely attack external ship components. Direct chemical corrosion attack occurs when certain chemicals are present in the internal holds and tanks of cargo ships. Elements such as chlorine and sulfur can readily attack the steel and cause accelerated corrosion and pitting [3].

Corrosion in ships can also be caused by microbiologically influenced corrosion (MIC). In this type of corrosion, microbial organisms present in the environment can accelerate corrosion. For example, sulfate-reducing bacteria (SRB), which are present in the stagnant water of many harbours, can build up on the hulls of ships. Other corrosion causing bacteria, such as acid producing and anaerobic bacteria, are also present in ballast tanks as well as in the liquid products of some tankers. These microbes cause a localized change in the environment, which can promote aggressive pitting and other types of corrosion. Pitting corrosion is a form of extremely localized corrosion that leads to the creation of small holes in the metal.

Stray current from cathodic protection can cause severe corrosion on ship hull [4]. Weld metal corrosion is an electrolytic action between the weld material and the base metal which can result in pitting or grooving corrosion. Implosion created by propeller can cause cavitaion on propeller blades. A crevice is a small gap, crack or hole in a material. Crevice corrosion takes place in these areas. In seawater, a buildup of chloride, silt, sand or other material takes place in a crevice [5]. These substances generally can't be washed out, and remain stuck in the crevice. A chemical reaction between the seawater and these substances takes place, leading to increasing acidity. As a result, corrosion begins and the metal becomes damaged. This can be identified by rusting or discolored patches on the metal's surface. Stress corrosion cracking takes place in specific areas of materials in seawater. This corrosion targets surfaces that are under more pressure than others. The hydrogen, chloride or sulphides in the seawater together with the stress that the metal experiences causes small cracks on the surface of the material [6].

Erosion corrosion is a degradation of material surface due to mechanical action, often by impinging liquid, abrasion by particles suspended in fast flowing liquid or gas, bubbles or droplets, cavitation etc [7]. High temperature or hot corrosion can occur in ships, primarily in the engine components, for example, gas turbine engines. The turbine blades made of nickel and cobalt based super alloys have been known to experience this accelerated form of corrosive attack and severe material deterioration.

3. CORROSION CONTROL

In a recent survey corrosion was found to be responsible for 30% of failures on ships and other marine equipment. There are four main methods for controlling the tendency of metals to corrode in sea water:

- Isolation of the corroding metal from the sea water by painting, or other coating
- Changing the potential of the metal to a point where corrosion ceases - by impressed voltage or coupling to a sacrificial anode.
- Making the metal passive, using corrosion inhibitors.
- Changing the pH of the local environment by chemical dosing.
- Making a change to a more corrosion resistant material.

3.1 Protection by Painting

Painting the ship isolates the steel from the corrosive media. The paint must also be resistant to the marine environment and the application strictly controlled to ensure full and effective coverage of the steel. Regular inspection and repair of the coating may be necessary to achieve reliable and lasting protection [8].

3.2 Cathodic Protection

Sacrificial anodes enable the potential of the system to be changed and will provide temporary protection to steel exposed by wear or damage of the protective coating. Systematic location of the anodes is critical to their overall effectiveness. They must likewise be regularly serviced and replaced when spent.

3.3 Inhibition

Inside the ship, inhibitors which modify the corrosion process may effectively prevent attack in bilges and other areas where sea water will collect and stagnate. Reliable systems to monitor and maintain the correct concentration of the inhibitor are an essential aspect of this prevention strategy.

3.4 Using Corrosion Resistant Alloys

Depending on design factors including the severity of the application and the levels of strength, damage tolerance, reliability, safety and life required, components and systems can be selected from composites, or from stainless steels of increasing resistance, or from copper based alloys such as cupro-nickel or nickel aluminum bronze, nickel alloys or titanium.

Protection for the least resistant alloys by anodes, or impressed potential, requires careful control of the system potential to avoid the possibility of hydrogen uptake by the more highly corrosion resistant alloys such as super duplex steel and titanium. In practice ships are rarely made just from a single metal or alloy. Modern engineering systems use a wide range composite and of metals and alloys, which are more or less resistant to marine corrosion than steel. The more resistant alloys may aggravate the attack on adjacent unprotected less resistant alloys. So, an overall protection by coating, anodes or inhibitors, selective use of more resistant metals is inevitable [9].

4. DEVELOPMENTS AND TRENDS

Investigations into a series of marine casualties have revealed that about 40% of them have resulted from structural failures, and corrosion deterioration is found to be the single largest factor leading to such failures. These studies have stressed the need for a more active attention towards preservation and maintenance of the metal and have led to major changes in the approach towards mitigation of corrosion. The absence of a regulatory requirement /standard for addressing corrosion was the first one to be addressed. The first recommendation came in 1996, with the enhanced program of inspection of the hull structures of bulk carriers and tankers, which specified the positive reporting of the condition of structural members in corrosion prone areas.

The Regulatory Environment generally prescribes adherence or compliance to the following norms:

- IACS ESP
- IMO A798
- SOLAS Reg 3-2, Part A-1
- age > 15 years, ‘GOOD’ in ballast/cargo spaces.

Bulk ship failures in the late 80’s lead the International Association of Classification Societies (IACS) to create the Enhanced Survey Programme (ESP) for the hull structure. The ESP mandated that all ballast tanks had to be coated with a “hard” coating and that the condition of the coating while the ship is in service must be “reasonable”. A shortwhile after that International Maritime Organization (IMO), a United Nations body, created Recommendation A798 in an attempt to bring the standard of work on new construction stage in line with what IACS would later require when the ships are in service. This recommendation was made mandatory in July 1998 by incorporation into IMO’s Safety of Life At Sea (SOLAS) in Part A-1, as Regulation 3-2[10].

In 2002, the IACS ESP was tightened again and the present requirement on coating condition in ballast tanks on tanker ships is quite stringent, and discussions of incorporating cargo tanks under the regime started [11]. In order to combat corrosion deterioration of hull structure, the fight should ideally begin from the building stage [12]. The first serious and implementable regulatory measure was made in 1998, by amending SOLAS to include a corrosion prevention system for ballast tanks. A series of tanker accidents led to more stringent requirements for tankers and “Condition Assessment Scheme (CAS) to ascertain the actual longitudinal strength after taking into account of the actual corrosion deterioration was made mandatory in 2002 for tankers older than 15 years. The class societies were following a system of assigning CAP notation prior to this, which was not mandatory. This was followed by a proposal in 2002 for ‘goal based ship construction standards’, which is under development at IMO. The goal based ship construction standards (GBS) require that the ships need to be designed and built to high standards, operated by trained and committed personnel; and maintained to high standards.

The tier-II functional requirements of Global based ship construction standards (GBS) cover corrosion control during the construction of a new ship and in her operational life. The conventional methods such as coatings, cathodic protection etc. will continue to be used, but regulatory requirements ensure that the above factors are taken care of by the concerned parties during the life of the ship. In July 2006, further stringent and mandatory measures were taken by amendments to SOLAS, specifying the ‘Performance Standard for Protective Coatings (PSPC)’, which stipulate the surface preparation and application of coatings at new-building stage and in their subsequent inspection and planned maintenance throughout a vessel’s life. The records of the coating are to be maintained throughout the life of the ship. In the changed scenario, all those involved during the lifecycle of the ship, i.e., the ship designer, constructor, surveyors, operators and repairers, have important role to play in mitigation of corrosion and extending the life of ship.

5. CORROSION MANAGEMENT IN SHIPS

Corrosion management is an open system analysis that brings all relevant information into a common platform to achieve a unified approach of problem solving and analysis from a single source [13]. A systematic approach of bringing all relevant data into a single source to maximize benefits is essential for corrosion management. Corrosion management is a system engineering strategy to improve the performance of engineering systems by specifically including people [14]. The management of corrosion is a concern which extends beyond the responsibilities of corrosion and materials engineers. Whilst they should provide advice during both the design and operational phase, they are dependent upon the co-operation of other disciplines if an installation, projected design life is to be achieved [15].

Successful management of corrosion means that corrosion hazards are identified and the associated risks are minimized by implementation of appropriate action before significant damage is caused by the installation [16]. Use of corrosion inspection and corrosion monitoring in a pro-active way (determining the deterioration rate and actions to change the rate) and predictive maintenance (maintenance actions based on the equipment condition) are effective strategies for corrosion management. They can require considerable initial expenditure but provide long term improved safety and economic benefits in terms of less unscheduled down time by ensuring cost effective selection of materials, chemical treatments, coating, cathodic protection systems and appropriate design. At present the term corrosion management can have different meanings for various workers defending on their specialist background [17]. In the context of present study the formal definition adopted by some workers for corrosion management is that part of the overall management system which is concerned with the development, implementation, reviews, and maintenance of the corrosion policy (Fig.1).

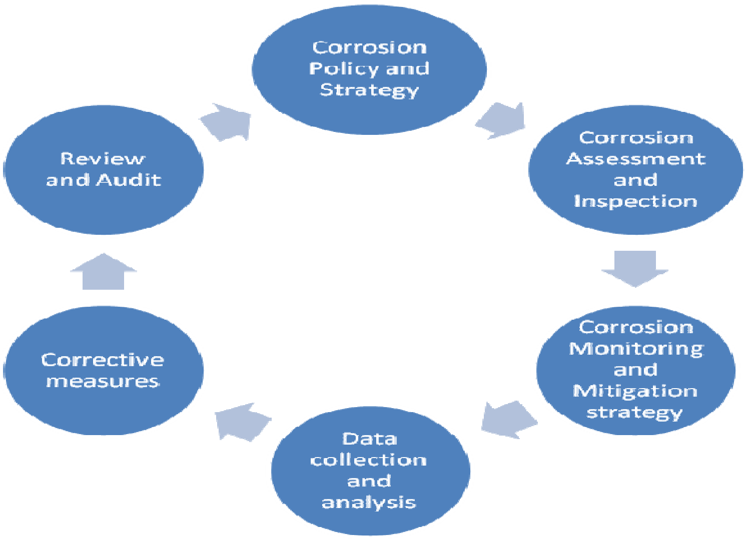

Figure 1. Corrosion management framework

Corrosion management covers a number of interrelated and complex issues in what are still developing subject areas [18]. It is important to identify good and poor corrosion control practice with a view of demonstrating how properly applied corrosion management can improve asset integrity and safety. The corrosion management lies within the function of many parts of the duty holder's organization and increasingly extends into contractor organizations. It is therefore important that corrosion management activities are carried out within a structured framework that is visible, understood by all parties and where roles and responsibilities are clearly defined [19]. The approach adopted by operators to the management of risks associated with corrosion and /or installation integrity is generally similar to that adopted for management of safety risks. Unmanaged corrosion can cause premature equipment failures leading to unnecessarily high operating costs and environmental problems [20].

Corrosion management is not a simple measurement of the corrosion rate. It includes the function of corrosion control technology selection, the application of corrosion control measures, and system modification. Collecting and compiling corrosion data play a predominant role in forming a structured corrosion analysis. Data essential for corrosion analysis originate from the area of operation, corrosion inspection, monitoring, corrosion control and asset maintenance. The data collected and brought to the common platform should be converted into information so that it may provide results to operation and maintenance personnel. Moreover an integrated approach toward problem solving is needed to deal with corrosive situations that arise from different areas of the operation. A practical corrosion management model for a commercial vessel is illustrated in Fig 2.

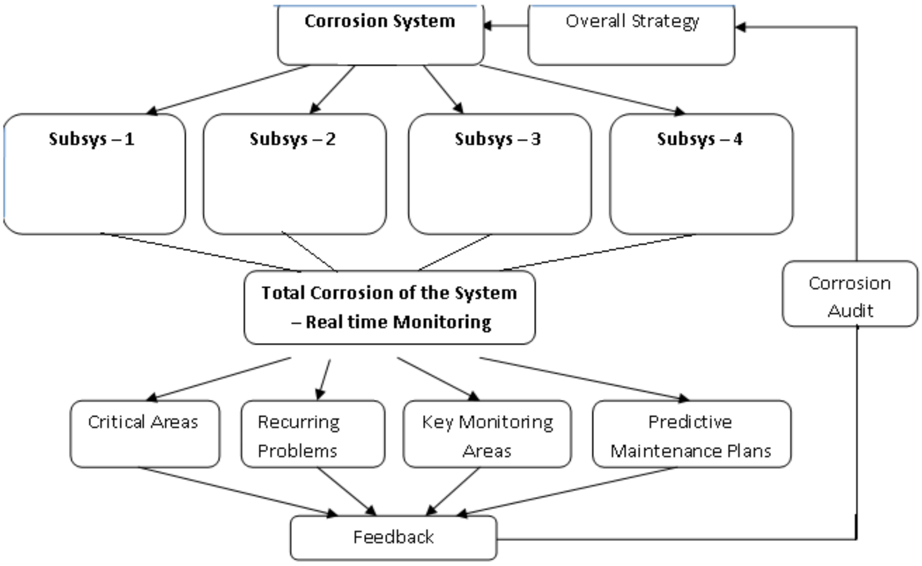

Figure 2. The Structure of Corrosion Management Model.

The success of corrosion management can be achieved through employing quality control and assurance procedures in different areas of corrosion management. Actually corrosion management is aimed at improving the conditions of critical components as well as ensuring proper control methods being implemented to check the integrity of assets and increase the service life. Corrosion inspection and monitoring data obtained from various monitoring methods will be utilized for assessing the performance of corrosion control systems and correlation of corrosion data from different sources can be done on the same platform. There is no integrated approach towards the management of corrosion in ship which is under operation. The frequent dry docking is avoided only if totality of the corrosion control practices is given full attention.

Managing corrosion is essentially people driven and heavily dependent on the contribution of everyone involved in ship operation. Without people being actively involved in the corrosion control practice, effective corrosion control is not possible. If an industry makes corrosion policy, the galvanization of all people into effective contributors to the corrosion control practice is a fundamental prerequisite. In general, the day the structure is placed into service, corrosion management begins. Corrosion management is term given to actively observing and assessing metal loss, while assuring that the functionality of the structure is maintained. An obvious example of the direct application of corrosion management with or without coating is the “corrosion allowance”. The corrosion allowance is the additional steel the designer will add to a steel plate and such practice is common and fundamentally sound practice. To ensure that a ship operates through its design life, it is essential that the operator does everything possible to keep the coatings intact. It is also essential to inspect the coating on a regular basis so that repairs can be made when needed, while the damage is minimal [21].

6. CONCLUSIONS

In order to reduce, if not eliminate, the effects of corrosion related failures, we must closely monitor the ship and corrosion prone areas. A marine vessel is a very large structure made of different metals and she operates in the most adverse environment. It shows that as there is no specific cure for corrosion, the effective exploitation of a combination of time tested and appropriate methods is the best solution to control corrosion. A combination of the preventive methods along with the active involvement of personnel in the shipbuilding and ship operation is essential to reduce the effects of corrosion.

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