

# Corrosion Management for effective mitigation of corrosion in Ships - Overview

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**Abstract:** This paper reviews the recent research and development in the area of corrosion management related to safety and reliability of ship structures. Important insights and findings previously obtained in the literature are summarized. Developments and trends made with respect to regulatory requirement /standard for addressing corrosion to ensure reliability of ship are discussed.

**Keywords:** Corrosion, Corrosion Management, Ship

## 1. Introduction:

Effective corrosion control in hull structure is one of the most important features for the shipping industry to ensure reliability and minimize risk and major removal of hull structure. The problem of hull corrosion has become a great concern for ship owners as they have increasingly recognized 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. 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. Corrosion management is concerned with the development, implementation, review and maintenance of the corrosion policy. The corrosion policy provides a structural framework for identification of risks associated with corrosion and the development and operation of suitable risk control measures. A policy is a directive that specifies how major operational issues should be handled over the longer term. The corrosion policy is to minimize the risk of failure and major renewal of hull structure and thereby extend the service life of ships by properly managing corrosion. It forms a basis for subsequent details in terms of strategies, organization structure, performance standards, procedures and other managerial processes. The corrosion strategy is the method by which the policy is implemented. The primary objective of this work is to provide information to ships owners and operators in shipping industries in the development and operation of corrosion management systems. This information will enable ship owners to protect their investment and safeguard the structural integrity of ships.

## 2. General Corrosion Management practice:

Corrosion process found in many industries are widely understood and mitigation procedures are well established (1). However, unacceptable problems such as leaks and emissions still occur. The general conclusion of some authors (2) is that the causes of corrosion related a failure is human error/poor management control. These causes include lack of inspection/monitoring, poor communication mal-operation, insufficient design review and inattention to warnings/ technical information. An overall system is therefore required to manage not only technical corrosion issues but also human response and actions. The management of corrosion is a challenge for the multi-disciplined team of operation, maintenance, inspection and materials and corrosion engineering staff concerned with process industry and only when their efforts are

successfully combined can the technical integrity of any structure be ensured at minimum life cycle costs. To ensure continued operation of plants at minimum cost, corrosion has to be actively managed through the life from the early stages of design until it is taken out of service. Corrosion audit is a corrosion management tool, which should be in place if effective corrosion management is to be achieved (3). Measurement made during inspection and corrosion-monitoring work is a major asset and such data in many cases accumulated at considerable cost is often under-utilized. However, a key factor in the use of inspection/corrosion data to provide for longer term planning of operations, maintenance and inspection requirements is the availability of a data base system to store and promote the collation and analysis of information.

Analyzing inspection and monitoring results should lead to condition status report, which may propose revising operation and maintenance practices, and inspection plans, for individual pieces of equipment, based on observed operational experience. When systematically registered and analyzed, inspection and corrosion findings will help identifying recurring problems allowing optimal use of existing technology. This can lead to substantial financial savings. 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. A systematic approach of bringing all relevant data into a single source to maximize benefits is essential for corrosion management (4). Corrosion management is a system engineering strategy to improve the performance of engineering systems by specifically including people.

Corrosion control will increasingly be considered as part of the wider discipline of corrosion management to reduce human errors and will provide the improved efficiency demanded by future generations. An integral part of system engineering approach is the development of new reliable knowledge based systems which have much to offer in reducing the erratic and aggravating influence of humans (5).

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 installations, projected design life is to be achieved (6). 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 sustained by the installation. 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 depending on their specialist background. In the context of present study the formal definition adopted by some workers (7) 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. Corrosion management covers a number of interrelated and complex issues in what are still developing subject's areas. 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. 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 (8). 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 predominant role in forming a structured corrosion analysis. Data essential for corrosion analysis originate from the area of process analysis, 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 towards problem solving is needed to deal with corrosive situations that arise from different areas of the operation (9).

The success of corrosion management can be achieved through employing quality control and assurance procedures in different areas of corrosion management. Actually corrosion management if 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 (10). There is no integrated approach towards the management of corrosion in ship, which is under operation. The frequent dry-docking be avoided only if totality of the corrosion control practices is given full attention. Corrosion process is continuously stimulated by external changes in seawater even though marine coating and cathodic protection are provided initially at construction stages. Managing corrosion is essentially people driven and heavily dependent on the contribution of every one involved in ship operation. Without people being actively involved in the corrosion control practice, effective corrosion control is not possible. If a industry makes corrosion policy, the galvanization of all people into effective contributors to the corrosion control practice is a fundamental prerequisite. Corrosion damages due to splash zone corrosion, concentrated corrosion and salt induced corrosion have been observed worldwide in port structure. Coating is applied to splash zone. Cathodic protection is required for prevention of concentrated corrosion, and both coating and cathodic protection are necessary to prevent salt-induced corrosion. To avoid unexpected large-scale rehabilitation measures as a consequence of negligence of periodic maintenance, systematical planning and budgeting of maintenance activities are necessary. Life cycle management (LCM), and its whole life costing (WLC), will contribute to a realistic approach of maintenance policy. In the author conclusion, LCM of port structures is desired as soon as possible and corrosion engineers should provide the owner with the know-how necessary for the LCM system from the viewpoint of corrosion and corrosion control(11). Corrosion is a slow process and can be detected for repair before causing any damage. Failure to do so would only cause expensive economical as well as physical damage to the structure itself. Corrosion management includes all activities performed during the service life of the structure to mitigate corrosion. Chew, We-sen carried out a study on corrosion management of steel reinforced concrete by data collected by questionnaire and interviews and the outcome of the study indicates that awareness of practicing professional is relatively low regarding issues on corrosion management. The potential cost saving through implementation of proper management program can be surprisingly high(12).

### **3. 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 since 2002

Bulk ship failures in the late 80's lead the International Association of Classification Societies (IACS) to create the Enhanced Survey Programme 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 short while 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 of 1998 by incorporation into IMO's Safety of Life At Sea (SOLAS) in Part A-1, as Regulation 3-2.

In 2002 the IACS ESP was tightened again and the present requirements on coating condition in ballast tanks on tanker ships is quite stringent, and discussions of incorporating cargo tanks under the regime started.

In order to combat corrosion deterioration of hull structure, the fight should ideally begin from the building stage. The first serious and implementable regulatory measure was made in 1998, by amending SOLAS to include a corrosion prevention system for ballast tanks. 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 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 the materials by which the ship is made of. Use of advanced electrolytic and resin coatings are being frequently used with success. Newer versions of Eddy current techniques are also being used. 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.

#### **4. Strategies for Effective Corrosion Management**

Understanding the corrosion and controlling it along with the process conditions that cause damage can only achieve effective corrosion management. An effective corrosion management is of utmost importance today, which, if better managed, can improve company's profitability considerably. The following strategies may be considered for

effective corrosion management.

Ø Establish the existence of corrosion

Ø Determine the contributory causes of corrosion.

Ø Monitor corrosion activity in real time along with the process conditions that can cause the damage.

Ø Multi technique corrosion monitoring approach, a combination of modern electrochemical techniques may be adopted to evaluate the corrosion behavior of a material and to get more realistic picture of corrosion in the pipeline

Ø Adopt systems integration approach for correlating data in real time to refine production-operating practices, chemical treatment programs and optimize costs.

Ø Practice an effective Data management approaches in the form of records before installation and removal of corrosion monitoring devices.

Ø Correct and appropriate condition assessment techniques should be used to avoid premature failure and ensure maximum safety.

Ø Continuously review the corrosion status of materials on-line and in conjunction with process data using multi-technique electrochemical corrosion monitoring.

Ø Review the periods between inspections using this level of control in place and the corrosion rate known and extend the periods between inspections to further reduce operation and maintenance costs.

Ø Device strategy for effective control of corrosion.

Ø Develop a feed back mechanism to assess the effectiveness of the corrosion control mechanism.

Ø Correlate the detrimental effect of corrosion

## 5. Conclusion

In order to reduce, if not eliminate, the effects of corrosion related failures, we must closely monitor the ship and corrosion-prone areas. Researchers have been struggling to find alternate materials and to devise novel methods to fight corrosion on commercial ships. Extensive amount of corrosion modeling and simulation activity is being carried out in research institutions across the globe. A marine vessel or for that matter a marine platform is a very large structure made of different metals and she operates in the most adverse environment. 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.

## 6. References

- [1] Corrosion control in petroleum production, TCP 5, Pub, NACE, 1 St Edn 1979.
- [2] R.W. Staehle, "The context and approach to life prediction of structures subject to environmental degradation in Cnf. Proc. Life prediction of corrodible structures, Hawaii, 1991, Pub NACE. Houston TX, 1991
- [3] D. Milliams, Corrosion Management 12 th International corrosion congress, paper No: 490, Houston, Texas 1993
- [4] Manickam Valliappan corrosion management of cooling water systems, Materials Performance ,Feb2002,41,2,pp42 Proquest science journals
- [5] Trethewey K.R. and Roberge Development of a knowledge elicitation for improved materials performance of marine systems, pp.63-76, NACE Houston Texas
- [6] Derek Milliams corrosion management, 12 th, Int Corr. Cong, Corrosion control for low cost reliability, 19-24 sep 93, pp 2420, Vol-4, Pub NACE International 1993.
- [7] D. Geary, J.L. Dawson and D.G John, An Historical Perspective of the management of aging infrastructures, NACE Meeting, Dubai, April 1997.
- [8] Corrosion Management Workshop sponsored by PTTC, June 25, 2005 in Farmington, New Mexico.
- [9] M. Valliappan, Computerised Multiplex Corrosion Management, Materials performance, NACE ,April-2005.
- [10] M. Valliappan, Corrosion Management for quality control and assurance, paper No.05059, Corrosion2005, NACE, and Houston, Texas.
- [11] Kazuaki Zen "Corrosion and life cycle management of port structures" Corrosion Science, 47 2353- 2360, 2005.
- [12] Chew, We-sen (2006) Corrosion Management of steel reinforced concrete. Masters thesis, University of Technology Malaysia
- [13] IMO regulations on corrosion mitigation
- [14] IACS Guidelines
- [15] GOI circulars on corrosion prevention
- [16] Accident Investigations of corrosion related damage
- [17] Eden, D.A., "Electrochemical Noise - The First Two Octaves", Paper No. 386, NACE, Corrosion 98, San Diego, California, March 1998.
- [18] Teevens, P.J., "Pressure Equipment Life Extension Through Advanced Corrosion Surveillance Methods", Paper 3, Session 8, Maintec, Birmingham, United Kingdom, March 1996.
- [19] A.K. Samant, "Corrosion Problems in Oil Industry – Needs More Attention", February 15, 2003
- [20] Eden, D.A., "Electrochemical Noise - The First Two Octaves", Paper No. 386, NACE Corrosion 98, San Diego, California, March 1998.