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# CORROSION GROWTH PREDICTION IN SEAWATER BALLAST TANK OF OIL TANKERS USING STATISTICAL MODEL

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A report submitted in partial fulfilment of the
requirement for the award of the degree of
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May, 2008

"I declare that this project entitled *"Corrosion Growth Prediction in Seawater Ballast Tank of Oil Tankers Using Statistical Model"* is the result of my own research except as cited in references. This project has not been accepted for any degree and is not concurrently submitted in candidature of any other degree"

Signature : ..........................

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Date : 02 MAY 2008

*Untuk suami tersayang, Rohaizat Ishak yang tidak jemu menyokong dan untuk anak manja mama Nur Adlin Dina Rohaizat yang sentiasa memahami mama dikala mama kesibukan.*

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## ABSTRACT

Ballast tanks need careful attention since they form the basic skeleton of a ship and the useful life of a ship is often dependant on the condition of its ballast tanks. The large and complex structure of a ballast tank coupled with frequent wetting and drying in highly corrosive salt water environment makes it one of the biggest maintenance burdens. Corrosion failure is considered as one of the important age related factors affecting structural degradation of ships in seawater environment. The analysis of this corrosion data is critical in order to predict the probability of failure for the structure. In current implementation, the mathematical models were used only to interpret the current condition of the corrosion. In this study, the improved mathematical models were used to predict not only the current condition of the ships but also to predict the future condition of the corrosion. The result shows that the improved models were able to conduct a future prediction which only considered an age related factor of the seawater ballast tank of oil tankers. Monte Carlo simulation has been used to predict the likelihood distribution of corrosion depth in the future at any point of time (vessel's age).

# ABSTRAK

Tangki Balas sesebuah kapal adalah satu struktur yang penting dalam menentukan jangka hayatnya. Strukturnya yang besar dan komplek dan sentisa diisi oleh air laut dan kering pada masa yang sama menyebabkan ia memerlukan kerja membaik pulih yang lebih kerap. Faktor pertambahan umur sesebuah kapal yang terdedah dengan persekitaran laut merupakan satu faktor penting kepada penyebab kegagalan kakisan dalam kemerosotan kekuatan stuktur. Analisa terhadap data kakisan yang genting adalah perlu dalam meramal kebarangkalian kegagalan terhadap struktur sesebuah kapal. Pada masa ini, model matematik untuk melihat tahap kakisan hanya boleh diguna pakai untuk keadaan semasa sahaja. Oleh itu dalam kajian ini, model matematik telah ditambahbaik untuk membolehkan ramalan boleh dibuat bukan sahaja untuk keadaan semasa pertumbuhan kakisan sesebuah tangki balas kapal malah pertumbuhan kakisan untuk masa hadapan juga boleh diramal. Hasil kajian mendapati penambahbaikan model ini boleh digunakan sebagai panduan untuk meramal kadar pertambahan kakisan di masa hadapan di mana hanya faktor masa atau umur sesebuah kapal yang diambil kira terhadap tangki balas kapal minyak. Simulasi Monte Carlo digunakan untuk meramal taburan kebarangkalian terhadap kedalaman kakisan pada masa hadapan untuk semua umur kapal.

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# LIST OF SYMBOLS

| | | |
|---|---|---|
| $\lambda$ | = | Exponential parameter also known as failure rate |
| $\delta$ | = | location parameter |
| $\theta$ | = | scale parameter |
| $\beta$ | = | shape parameter |
| $\sigma^2$ | = | variance |
| $\sigma_x$ | = | standard deviation |
| $\mu_x$ | = | mean value |
| $\mu$ | = | mean |
| $d_{ave}$ | = | linear regression model of defect depth average |
| $d_g$ | = | degree of freedom. |
| $E$ | = | expected frequency |
| F | = | cumulative distribution function |
| $k_n$ | = | number of classes. |
| $N$ | = | class size |
| $O$ | = | observed frequency |
| $R^2$ | = | coefficient of determination |
| $std_d$ | = | linear regression model of defect depth standard deviation |
| $t_v$ | = | age of vessel |
| u | = | random variables generated |
| $x_o$ | = | an offset, which is assumed to be known a priori (the smallest value) |
| $Y_u$ | = | upper limit of selected class |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Marine corrosion is a constant and continuing process. Structural failures such as explosion and leakage may induce serious damages and cause environmental hazards. Heavy financial loss associated with production loss, repair or even the clean up of the polluted marine environment will be experienced by the company. Therefore, many researches have been carried out to monitor the corrosion progress continuously in order to avoid such damages. But their result in prediction of corrosion growth is limited to the duration of ship's age. Thus, in this study we used statistical and probabilistic approach to give a better prediction and solution on maintaining and controlling the corrosion effects. In other words, the remaining life-time of structure and the its probability of failure can be quantified and projected accurately for the future. Monte Carlo method is applied in order to simulate the corrosion growth based on the given ship's age.

Corrosion is an electrochemical process required an anode, a cathode, and an electrolyte. Electrical current flows between the cathode and anode, and the reaction results in an increase in metal volume as the Fe (iron) is oxidized into $Fe(OH)2$ and $Fe(OH)3$ and precipitates as FeO OH (rust colour). Water and oxygen must be present for the reaction to take place. These elements that exist especially in seawater environment which in this research involved the study of ballast tank of oil tanker will be further worsened by the corrosion specifically pitting or grooving (Francis, 1975). Corrosion growth in sea water ballast tank is depending on several factors: material properties, operational condition, environmental parameters and ship lifetime (i.e., age). The level of corrosion growth can be controlled and maintained in certain age to minimize the damages or failures caused by corrosion. Because of this, age is a major factor to be considered in order to predict the corrosion growth so that an effective action or response can be taken at a suitable and accurate age.

Pitting is a form of extremely localized attack of corrosion which causes the metal to go into solution more rapidly at that spot than at any other adjacent area. In ballast tanks pitting corrosion mainly occurs due to irregularities in coatings due to improper surface preparation and coating practices. Though pitting may or may not result in the formation of holes in the metal, it causes major damage to the structural integrity of the tank sometimes resulting in its serious failure (Rogers, 1968).

On the other hand, ballast tank is a compartment within a boat or ship, that holds water. A vessel may have a single ballast tank near its center or multiple ballast tanks typically on either side. A large vessel typically will have several ballast tanks including double bottom tanks, wing tanks as well as forepeak and aftpeak tanks. Adding ballast to a vessel lowers its center of gravity, and increases the draft of the vessel. Increase draft may be required for proper propeller immersion. A ballast tank can be filled or emptied in order to adjust the amount of ballast force. Ships designed for carrying large amounts of cargo must take on ballast water for proper stability when travelling with light loads and discharge water when heavily laden with cargo. Small sailboats designed to be light weight for being pulled behind automobiles on trailers are often designed with ballast tanks that can be emptied when the boat is removed from the water. In submarines ballast tanks are used to allow the vessel to submerge, water being taken in to alter the vessels buoyancy and allow the submarine to dive. When the submarine surfaces, water is blown out from the tanks using compressed air, and the vessel becomes positively buoyant again, allowing it to rise to the surface. A submarine may has several types of ballast tank, the main ballast tanks: which are the main tanks used for diving and surfacing, and trimming tanks, which are used to adjust the submarine's attitude both on the surface and when underwater.

## 1.2 Research Problem

Previous researchers (e.g. Paik et.al, 2003; Melchers, 2001; Garbatov, 2003) have proposed statistical methods and realibility analysis approaches as solutions to obtain better information and understanding on data collected from real inspection of vessel's ballast tank. Although their proposed methods and approaches can give better interpretation of corrosion growth, unfortunately their solutions still have several limitations and drawbacks.

In specific previous works applied complex empirical model parameter and statistical techniques which made them hardly to be directly understood by plant engineers and inspection personnel. In additional, the guidelines for data analysis are not conveniently available in simplified form to suit the application on site. The data used were enormous, but there is no standard statistical analysis available for inspection data relating to corrosion measurement. Therefore, in our work, we combined data for multiple vessels into one database. Last but not least, previous models are generally developed based on experimental work in the laboratory, thus they did not give practical solutions and real/exact simulation to the real event on site. As a result, in our work, we used real inspection data to generate real simulation of the corrosion growth for the ballast tank of oil tankers.

## 1.3 Aim and Objective

The aim of this research is to develop time-dependent statistical models of corrosion depth for seawater ballast tank of oil tankers. Based on this, our objectives are:

a. To analyses the real inspection data of corrosion depth using statistical approach.

b. To developed corrosion growth model using probability method.

c. To predict the future growth of corrosion dimension at any point of time.

## 1.4 Scope of Work

This study concentrates on the analysis of corrosion data collected from real inspection data (i.e., ship's age and corrosion depth in millimeter (mm)). The effects of material properties, operational condition, and environmental parameters upon corrosion growth are not considered in developing the generic assessment model of the corrosion data. A statistical method is used to find the patterns and variation of corrosion growths. The results gathered are then used to assess the current and future remaining lifetime of corroding ballast tank using the Monte Carlo simulation procedure.

## 1.5 Expected Finding

The study shows the pattern of distribution based on real inspection data of corrosion depth and a corrosion growth model that shows a depth of corrosion for unlimited age of ship. Findings from this study are capable in reducing the uncertainties associated with corrosion data, environmental loading and material properties, hence, assisting operation management in making decision on what, when and where the future inspection, repair, maintenance and replacement should take place. In fact, it will improve the accuracy of ballast tank of oil tanker assessment in order to secure the ballast tank reliability for a given service period.

## 1.6 Study Organisation

The study is organised in five chapters. Chapter 1 comprising the problem background, research aim and objectives, scope of work and expected finding of study. Chapter 2 covers literature review section, which discusses the topic of submarine Ballast tank including Archimede’s Law, corrosion and prevention and the previous research papers to give a more idea to review the past problems. Then, Chapter 3 presents the research methodology. Chapter 4 initiated the research work by presenting the statistical analysis and result of the analysis then followed by integrity simulation analysis.  Lastly, all the research work are summarised and concluded in Chapter 5. This organisation can be map via organisation chart (Figure 1.1).

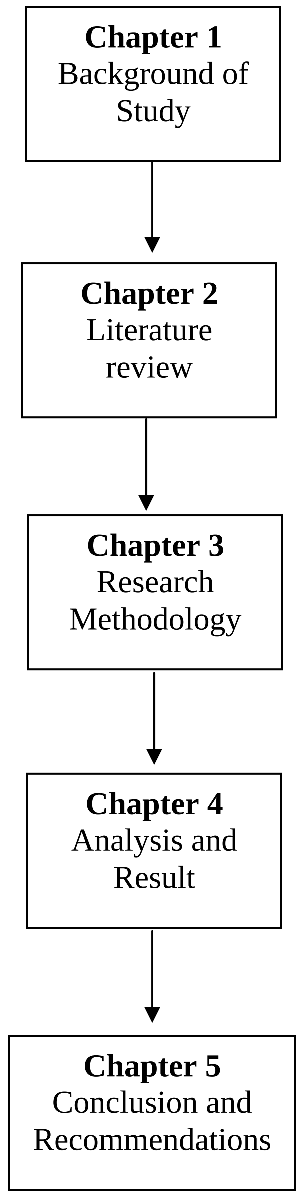


**Figure 1.1**: Chart of Study Organisations