ULTIMATE STRENGTH ANALYSIS OF SHIPS PLATE DUE TO CORROSION

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To my beloved mother, *Kamariah* and father, *Lazim,* my sisters, *Nuha,* and *Madihah* who are never fail to give me a full of supports in the journey of my study.

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ABSTRACT

Today in maritime industry, it is a mandatory task to compute the ultimate strength of structural components and their system for structural design and strength assessment based on ultimate limit states. Increasing the number of ship failure because of structural incapable to support the load have gain the motivation and interest to study the ultimate strength of the ship's structure. One of the reason of ship structural failure mainly because of ship's plate corrosion. Through this thesis, the study have found out that decreasing thickness of the plate due to ship's plate corrosion will decrease the critical load of the ship's plate itself. The study concern about compressive uni-axial loading on the ship's plate which resulting linear and nonlinear buckling effect. The critical load of the ship's plate structure is study using method eigenvalue linear buckling analysis by ABAQUS Finite Element Software packaged. The result show that more lower the critical load by the structure, more tendency the structure will fail and reach the un-stability mode of deflection. The ultimate compressive strength on the other hand showing the strength of the ship plate under condition of nonlinear buckling analysis. The condition which ship plate located at the bottom and middle section of bulkhead experienced more compressive stress compare to other part in ship. This is according to maximum moment according to shear force-moment diagram of any ship that gives the maximum moment stress at the middle of the ship. Finding ultimate strength of the ship's plate gives the understanding about the concept of allowable limit load the ship structure can withstand under ship service loading. The parameter of plate slenderness ratio is important for linear and nonlinear ship's plate buckling analysis and the ultimate strength is calculated based on formula by Faulkner.

ABSTRAK

Hari ini dalam industri maritim, ia merupakan satu tugas yang wajib untuk mengira kekuatan muktamad komponen struktur dan sistem mereka untuk reka bentuk struktur dan penilaian kekuatan berdasarkan keadaan had muktamad. Meningkatnya bilangan kegagalan kapal kerana tidak mampu untuk menyokong beban struktur telah membawa motivasi dan minat untuk mengkaji kekuatan muktamad struktur kapal. Salah satu sebab kegagalan struktur kapal terutamanya kerana pengaratan pada plat kapal. Melalui tesis ini, kajian telah dipelajari bahawa pengurangan ketebalan plat kerana pengaratan pada plat kapal akan mengurangkan beban kritikal plat kapal sendiri. Kajian mengambilkira tentang mampatan beban uni-paksi pada plat kapal yang menyebabkan kesan lengkok linear dan tak linear. Beban kritikal struktur plat kapal adalah kajian menggunakan kaedah lengkok linear '*eigenvalue*' analisis menggunakan '*ABAQUS Finite Element Software packaged*'. Keputusan kajian menunjukkan hasil yang lebih rendah beban kritikal pada struktur, lebih kecenderungan struktur akan gagal dan mencapai mod ketidakstabilan pesongan. Kekuatan mampatan muktamad sebaliknya menunjukkan kekuatan plat kapal dalam keadaan analisis lengkokan tak linear. Keadaan plat kapal yang terletak di bahagian bawah dan bahagian tengah 'bulkhead' kapal mengalami lebih mampatan berbanding dengan bahagian lain dalam kapal. Ini adalah berpandukan momen maksimum mengikut gambarajah ricih-momen mana-mana kapal yang memberikan tekanan momen maksimum di tengah-tengah kapal. Mencari kekuatan muktamad plat kapal memberikan pemahaman tentang konsep beban had yang dibenarkan struktur kapal yang boleh ditahan dalam beban semasa penggunaan kapal. Parameter '*plate slenderness ratio*' adalah penting bagi analisis plat kapal lengkokan linear dan tak linear dan kekuatan muktamad dikira berdasarkan formula oleh Faulkner.

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LIST OF SYMBOLS

β	-	The plate slenderness ratio
b	-	Longitudinal stiffener's plate spacing
a	-	Transverse stiffener's plate spacing
σ_y	-	Yield's Strength
E	-	Modulus of Elasticity
V	-	Poisson's Ratio
σ_c	-	Buckling Stress
$\emptyset_b$	-	Ratio between buckling stress and yield stress
R_{xu}	-	Ultimate strength reduction factor for axial compression loads
σ_{xu}	-	Ultimate compressive strength for a plate with pit corrosion
σ_{xuo}	-	Ultimate compressive strength for an intact plate
A_o	-	Original cross-sectional area
A_r	-	Minimum cross-sectional area with pitting corrosion

LIST OF ABBREAVIATION

IMO	**-**	International Maritime Organization
ISSC	**-**	International Ship and Offshore Congress
ISO	-	International Organization for Standardization
IACS	-	International Association of Classification Societies
FEA	**-**	Finite Element Analysis
FEM	**-**	Finite Element Method
ULS	**-**	Ultimate limit states
CSR	-	Common structural rules
DNV	-	Det Norske Veritas

CHAPTER 1

INTRODUCTION

1.1 Introduction

Today in maritime industry, it is a mandatory task to compute the ultimate strength of structural components and their system for structural design and strength assessment based on ultimate limit states (ISO, 2006, 2007; IMO, 2006; IACS, 2006a, b). This is because it is not possible to determine the true margin of structural safety as long as the ultimate strength remains unknown Paik et al, (2008).

Although the ANSYS nonlinear FEA may be the most refined method among the candidate methods, and believed to give the most accurate solutions, it is important to realize that the modelling technique applied must be adequate enough in terms of representing actual structural behaviour associated with geometrical nonlinearity, material nonlinearity, type and magnitude of initial imperfections, boundary condition, loading condition, mesh size, and so on. Otherwise, the resulting computations may be totally wrong. For the present benchmark study purpose, the elastic-perfectly plastic material model is applied for all the candidate methods by neglecting strain-hardening effect of the material.

Buckling strength analysis of plates and stiffened plates was the subject of many researches. (Liu et al, 2008) have used energy method to study elastic stability of simply supported rectangular plates under any combination of in-plane loads. Maiorana et al. (2008) have analysed elastic buckling of un-stiffened plates under interacting patch loading and bending moment. Steen et al, (2008) have studied elastic buckling and post-buckling of bi-axially compressed plates. Bringhenti, (2005) have investigated buckling failure of plates with cracks.

The project is about method of solving the marine structure problem using FEM software. The selected structure is plate on ship structure, the problem was the safety of the ship by determining the ultimate strength of plate that having pit defect because of aging. This result in the project are compare with result by other researcher having similar size and loading condition of ship plate structure. This considered as influencing variable contributing to the safety factor of the investigated structure. The safety's factor of the structure or safety margin determine from the value of design demand, the value of design demand by the structure is the minima require value for the plate ship structure to be able to deliver its function for overall ship structure.

In world maritime industry, substantial efforts have been directed by various stakeholders such as IMO, ISO, and IACS, toward the application of advanced methodologies such as:

a) Goal-based design using first-principles-based direct methods;
b) Limit states-based methods;
c) Risk-based methods.

The present study is concerned with ultimate limit states (ULS) which are the common aspect of the three technologies noted above. It has been well recognized that the ULS approach is a better basis for design and strength assessment than the traditional allowable working stress approach, the latter being primarily based on linear elastic method solutions alone. This is because it is not possible to determine the true margin of structural safety as long as the ULS remains unknown. While the margin of safety can be determined by a comparison with the ultimate strength and the design working stress, it is essential to accurately predict the ultimate strength within the design framework.

Some benchmark studies on the methods of ultimate strength computations for plate elements, stiffened panels and ship's hull girders Paik et al, (2008) were previously investigated. In the present study, some useful insights on the application of non-linear finite element (FE) methods are developed in terms of structural modelling. As an illustrative example of the structure, the present study adopts steel stiffened-plate structures which are the most important structural parts in outer bottom of ships and ship-shaped offshore installations. The object structure is considered to be subject of bi-axial compression.

1.2 Problem Statement

Most of ship plate or ship stiffener and ship hull around the world are made of steel. Steel material tend to corrode due to certain environment condition. The ferum oxide $Fe(OH)_3$ layer called corrosion form in different rate depending on the situation. In case of chemical ship's carrier, certain chemical rise the rate of corrosion. Although the ship structure made of steel is coating to prevent the corrosion but the coating also wear out due to service life of the vessel and several other reason. Many researcher found out that one of the reason the failure of structure integrity on global ship's structure or local ship's structure because of corrosion. Every year or every agreed period, on the matter of ship structure safety, the port state require to check the ship plate thickness to ensure the safety of the ship. The safety is important in term of ship's business and in aspect of human lives.

The ultimate strength limit state approach is a better basis for design and strength assessment of various types of structures than the traditional allowable working stress approach because it is not possible to determine the true margin of structural safety as long as the limit states remain unknown. In recent years, substantial efforts by stakeholders such as International Organization for Standardization (ISO), International Maritime Organization (IMO), and classification societies have been directed to the developments of limit state based standards. (Paik et al, 2008)

1.3 Objective of the Research

The objective of the research is finding the ultimate strength of the ship's plate due to corrosion. The corrosion being investigated is general corrosion which is the thickness is decrease uniformly by ship's plate thickness. The project first study about the critical loading on ship's plate and then study the ultimate strength on the ship's plate. The modelling of the ship by parameter of geometry and material properties is referring to previous other publish work.

1.4 Scope of the Research

The scope of the research throughout the master project on the study about ship's plate linear and nonlinear buckling analysis are listed below:

1. The deflection occur only at plates, not at the stiffeners. The geometry of the ship plate fixed.
2. The temperature have no effect, low temperature makes the structure material properties becomes brittle. The effect of the residual stress from the welding are also neglected.
3. There are no effect of welding (residual stress) from assembly between plate and stiffener.
4. Assume the corrosion only uniform corrosion on plate, not other kind of corrosion such as pit corrosion. The corrosion causing uniform thickness

reduction also recognized as general corrosion from the others publish work. (pitting corrosion)

5. Assume the material only use is general material use for plate construction for ship which is mild steel. The material properties of ship's plate based on oil tanker double hull ship plate based on CSR 2006 by IACS of double hull tanker.
6. The study is based only on longitudinal stress uniaxial compression loading on the model.

1.5 Significant of the Research

The significant of the research is being able to find the ultimate strength and critical load of the ship's plate. The ship's plate is fundamental structure of ship's plate which is the first failure happen at the ship plate because the ship plate govern most part of the ship structure. Ship's plate location for example at the side of the ship which is hull, at the deck floor of the ship and at the bottom of the ship. The knowledge of finding ultimate strength by famous researcher which investigated only the ship structure such as Jeom Kee Paik, Faulkner, Shengming Zhang and several other with engage to DNV and IMO classification bodies with the ISSC conference also put the focus of the significant of the project in the higher level.

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