FINITE ELEMENT ANALYSIS OF 3D STEEL JACKET FRAME (OFFSHORE STRUCTURE) USING ANSYS

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ABSTRACT

Jackets were among the very first structures that used in the offshore industry, as stable platforms mainly for oil and gas production facilities. Frame is one of the important elements of this structure. Unfit or improper design can lead to the failure of a structure. The steel jacket frame was analyzed by manual calculation and also design in ANSYS software. There are several methods can be used to analyses the behaviour of steel jacket frame. However, among all these methods, finite element method and probabilistic method will be a very effective method to obtain the strength and behaviour of steel structure. This analysis is to determine the behaviour of frame design for the jacket structure. This research will mainly focus on the steel frame of jacket platform. The yield strength of steel jacket that used is 500 N/mm^2 which is the strongest steel. The value for the input variables are generated randomly by using Monte Carlo Simulation or as prescribed samples using Response Surface Methods. 1000 simulations had been made to make sure the analysis is more precise and accurate. Here, the study was conducted to prove that a steel jacket under the existence of randomness and uncertainty can be analyzed by apply probabilistic finite element analysis using ANSYS.

ABSTRAK

Jaket adalah antara struktur yang pertama yang digunakan dalam industri luar pesisir, sebagai platform stabil terutamanya untuk kemudahan pengeluaran minyak dan gas. Frame adalah salah satu elemen penting dalam struktur ini. Reka bentuk tidak layak atau tidak betul boleh menyebabkan kegagalan struktur. Rangka jaket keluli dianalisis dengan pengiraan manual dan juga mereka bentuk dalam perisian ANSYS. Terdapat beberapa kaedah yang boleh digunakan untuk menganalisis kelakuan kerangka jaket keluli. Walau bagaimanapun, di kalangan semua kaedah ini, kaedah unsur terhingga dan kaedah kebarangkalian akan menjadi kaedah yang sangat berkesan untuk mendapatkan kekuatan dan kelakuan struktur keluli. Analisis ini adalah untuk menentukan kelakuan reka bentuk bingkai untuk struktur jaket. Kajian ini akan memberi tumpuan pada rangka keluli platform jaket. Kekuatan alah jaket keluli yang digunakan ialah 500 N/mm^2 yang keluli yang paling kuat. Nilai untuk pemboleh ubah input yang dijana secara rawak dengan menggunakan Monte Carlo Simulasi atau sebagai sampel ditetapkan menggunakan Kaedah Respon Permukaan. 1000 simulasi telah dibuat untuk memastikan analisis yang lebih tepat dan tepat. Di sini, kajian ini dijalankan bagi membuktikan bahawa keluli jacket yang mengalami masalah kerawakan dan ketidakpastian boleh dianalisis dengan menggunakan cara analisis terhingga dan analisis kebarangkalian di bawah penolongan perisian komputer ANSYS.

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LIST OF SYMBOLS

d	Outside Diameter
t	Thickness
d/t	Ratio for Local Buckling
A	Area of section
I	Moment of inertia
W_{pl}	Plastic modulus
i	Radius of gyration
N	Axial load
V	Shear force
M	Moment
I_T	Torsional Constants
$\gamma M0$	Partial factor for resistance of cross-sections whatever the class is
$\gamma M1$	Partial factor for resistance of members to instability assessed by member checks
λ	Slenderness value
$\emptyset$	Value to determine the reduction factor
X	Reduction factor
L_{cr}	Buckling Length
K_{zy}	Interaction factor

LIST OF ABBREVIATIONS

2D	Two Dimensional
3D	Three Dimensional
CIVIFEM	Civil Finite Element Method
LatBuck	Lateral Buckling
ChckAxis	Check Axis
BMSHPRO	Beam and Shell Properties
CS	Coordinate System
LS	Load Step
DOF	Degree of Freedom
PRES	Pressure
GAUS	Gaussian
DENS	Density
ELASTIC	Elastic modulus
POISON	Poison ratio
LOAD	Point load
WINDLOAD	Wind load
TEMP	Temperature
PDF	Probabilistic density function
CDF	Cumulative distribution function
MAXIMUMDEFLECTION /MAX_DEFLECTION	Maximum Deflection

CHAPTER 1

INTRODUCTION

1.1 GENERAL

The finite element analysis is a numerical technique. It was an extension of matrix method of structural analysis. In finite element method, actual component is replaced by a simplified model, identified by a finite number of element connected at common point called nodes, with an assumed behavior of each element to the set of applied load, and evaluating the unknown variable such as displacement.

Since sixty years ago, the offshore structure is the bigger structure in oil and gas industry and it growing quickly over time (M.H. Patel 1989). Fix steel structure (D.J. Wisch 1998) was studied that the design of structure will be considered by load and the increasing of water depth. A simple model whole shape frame jacket will be proposed and modelled by the software ANSYS in three directions, then finite element calculation were carried out through the software to obtain the deflection, stress and strain and buckling of steel structure jacket. All these analysis were based on finite element method. Probabilistic analysis will be carried out by changing the input parameters and properties of steel to find out which affect the frame effectively.

The analysis of steel frame jackets can be done by hand calculation easily if the structure of frame is simple. However, if the structure of steel frame is complicated, the

analysis will involve many long and mathematical calculation may take long time to complete all the calculation. Nevertheless, with the increasing of computer technology all around the word, people nowadays are able to solve the analysis of a structure by using software in computer such as STAAD Pro, SACS, SAP 2000, and etc.

1.2 PROBLEM STATEMENT

Jackets were among the very first structures to be used in the offshore industry, as stable platforms mainly for oil and gas production facilities. Frame is one of the important elements of this frame structure. Unfit or improper design can lead to the failure of a structure. There are several methods can be used to analyzes the behavior of steel jacket frame. However, among all these methods, finite element method will be a very effective method to obtain the strength and behavior of steel structure.

Most of the times, engineers need to find out an accurate data of deflection and stress for the structure before he start design. A lot of time had been wasted for that works. By applying the probabilistic analysis, a range of result can be obtained by input the loading and the wind load. So, engineers works can be reduced and save more time for others.

1.3 OBJECTIVE

This thesis have a few objectives that related to the design of steel structure. There are many thing that should be considered to make this project more reasonable with the objective. The objective that use for this project must be achieve. The ultimate purpose of this study is to study the strength and behavior of steel jacket frame by using a finite element analysis software ANSYS.

i. To determine the force and moment, stress & strain and deflection on steel jacket structure using ANSYS software.
ii. To verify the steel jacket frame is stable against the variable load
iii. To determine probabilistic analysis of steel jacket frame

1.4 SCOPE OF STUDY

This research will mainly focus on the steel frame of jacket platform. In order to achieve the objective of this research, there are a few scope of work that important to be revised and followed, such as:

i. Result of analysis on steel structure (stress, strain, deflection)
ii. Develop a model on ANSYS software for analyzing steel jacket structure
iii. Conduct probabilistic response analysis on steel jacket structure

First step is install the ANSYS software to the computer and do all the tutorials that given on this software. The basic tutorial will increase the skills on modelling and analyzing all structure in ANSYS. Then, the properties of structure steel must be define which include their dimensions and the section on jacket structure. The type of structure can be determine by referring plans or assumptions. Preprocessing is the step to define lines and key points. It will be continue to next step. All environmental load and supports will assign to the modelling structure. After that, determine the solution of the structure which is deflection and stress. Finally, carry out probabilistic analysis and observe the result of that occur on structure.

1.5 EXPECTED OUTCOME

This research claims to find out the behaviors and passing code checking of 3D portal frame. The behaviors are deformation, deflection, tension checking, compression checking and lateral torsional buckling checking according to Eurocode 3.

1.6 SIGNIFICANCE OF STUDY

This research will be a significance endeavor in providing the information about the steps and results of analyzing steel jacket frame by using ANSYS. Maximum deformation, deflection axial stress and strain are able to be determined. It is really good to practice to analyze and make sure it is safe before constructing it. This definitely will enhance the reputation of Malaysia with advance engineering skills.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION OF FRAME JACKET PLATFORM

Nowadays, steel is most one material that used in construction industrial. It's because, steel have more advantage than timber and other material. (K.Sadeghi 2001) provide a review of the literature on design and structure of offshore jacket platform. The jacket platform have difference type depends on their design such as towed to drilling site, three or four 'legs' are piled on the sea bottom. Jacket rig also suitable for shallower water and their legs were extend down to deeply in the water. The jacket is design for fix structure and the advantage of this structure is their stability because they are attached to the sea floor. So that, all the variable load applied on the structure can be covered by the structure. Besides that, jacket structure also will be stable. However, this jacket cannot used in very deep water and it's also not economical to build legs that long.

(Sadeghi 2001) stated that fix Jacket platform is made of steel and template platform mostly consist of jacket, deck and piles. Jacket offshore structure are exposed to many of external load such as wave load, wind load, earthquakes, ship-berthing impact, and operation load. (M.J. Terro, M.S. Mahmoud, M. Abdel-Rohman 2004) researched that the large deformation and fatigue damage will come when the structure properties are liable to induce self-excited force. (Adrezin 1996) studied the offshore structure was focusing in particular on the various model. Some of researchers investigated that only

the loads acting on the structure. (Kim at al. 2011) studied the steel buildings was sensitive because of the design parameters subjected to progressive collapse.

Frame steel jacket is the most structure that use in offshore platform. Among the various types of offshore structure, the steel structure of jacket platform is the most common used in oil and gas industry because it is multi-functions for oil exploration, drilling, as well as for production. Usually, this structure operate up to depth of about 100-150 meters. Besides that, the maintenance and repair of the structure is more difficult than large infrastructure on land.

2.2 MODEL OF JACKET OFFSHORE PLATFORM

According to (Poona Mohan, 2013), software is the easier for offshore engineers to do simplified and realistic evaluation of the static operation and ultimate limit characteristic of jacket platform that subjected to various environmental condition. The jacket is modeled as a frame in three dimensional spaces. Figure below shows the real model that used for modelling the jacket structure. Figure 2.1 show the real model on offshore jacket platform

Figure 2.1: Real model on offshore jacket platform

2.3 PROBABILISTIC ANALYSIS IN FINITE ELEMENT MODELLING

(Tie Ming 2011) stated that the probabilistic analysis method was applied to account for the variability in fiction. In this study, Monte Carlo simulation was used to analyze the effect of parameter uncertainty for the structural analysis. From the analysis result, it was observed that the changes in pre-stressing force, elastic modulus of pre-stressing steel, which need to be tightly controlled. As a result, from deterministic analysis and probabilistic analysis, it was found that probabilistic analysis tends to be closer to reality and gives a way of designing for quality.

Recent trends of structural mechanics applications in finite element analysis demonstrate an increasing demand for efficient analysis tools. Using ANSYS, finite element models were developed to simulate deflection behavior. Probabilistic analysis methodology could predict the response on stress, strain, and deflection due to various combination of input variables. Figure 2.2 show the example of structure fixed jacket platform by ANSYS software

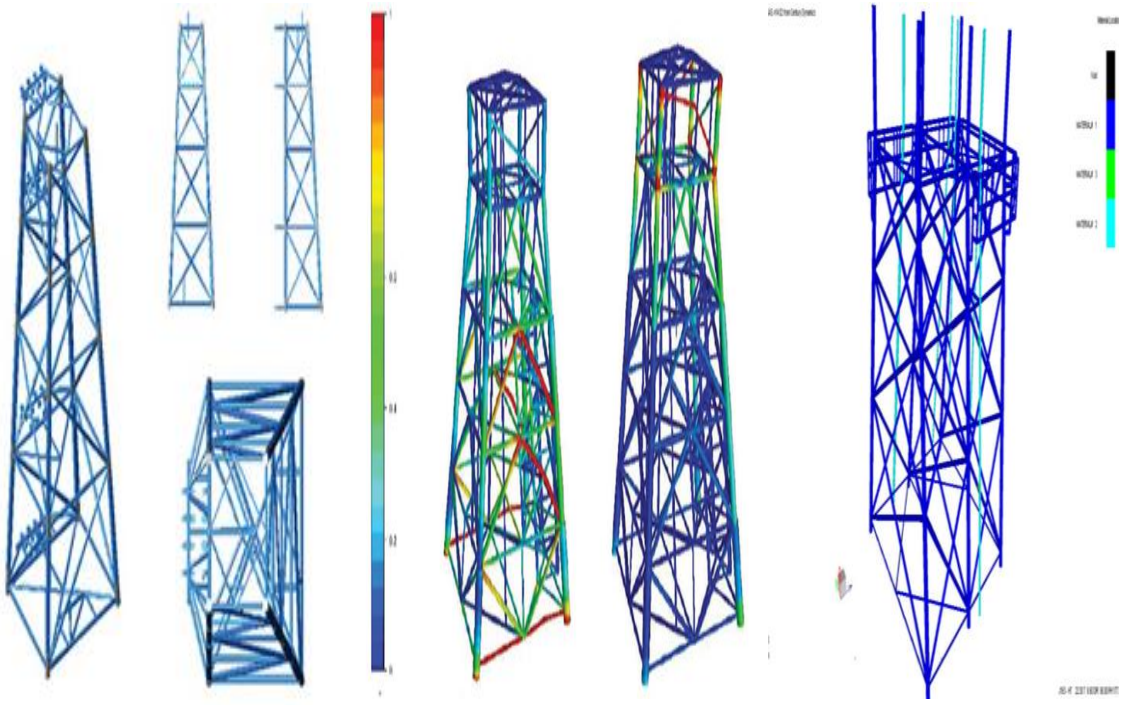

Figure 2.2: Example of structure fixed jacket platform by ANSYS software

2.4 FINITE ELEMENT ANALYSIS

In research of (K.S Sivakumaran, 2001) a finite element analysis model for the post-local buckling behavior of steel members exposed to axial compression has been develop. The finite element model consists of a shell finite element and experimental-based material properties model to represent the body of steel section. A special loading or environmental various were employed to obtain uniform displacement condition at the loading edges. The compression between the test result, and the finite element result was performed for axial and lateral displacement behavior, buckling load, ultimate loads, and axial stress distribution.

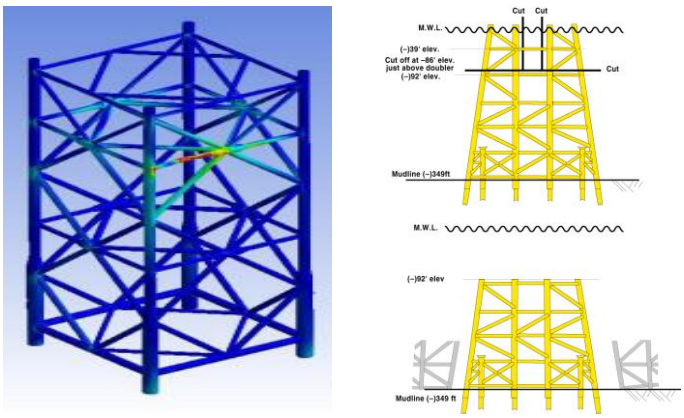

Figure 2.3: Example of model for design steel jacket platform

2.5 PROBABILISTIC DESIGN

Computer models are expressed and described with specific numerical and deterministic value; material properties are entered using certain values, the geometry of the component is assigned a certain length or width, etc. An analysis based on a given set of specific numbers and values is called a deterministic analysis. Naturally, the results of a deterministic analysis are only as good as the assumptions and input values used for the analysis. The validity of those results depends on how correct the values were for computer under real life conditions.

2.5.1 General

In reality, every aspect of an analysis model is subjected to uncertain in some way. Material property values are different if one specimen is compared to the next. This kind of uncertain is inherent for materials and varies among different material types and material properties. For example, the uncertain of the elastic modulus for many materials can often be described as a Gaussian distribution with standard deviation of ±3-5%. Likewise, the geometric properties of components can only be reproduced within certain manufacturing tolerances. The same variation holds true for the loads that are applied to finite element model. This means that almost all input parameters used in a finite element analysis are inexact, each associated with some degree of uncertainty.

It is neither physically possible nor financially feasible to eliminate the uncertain of input parameters completely. The reduction of uncertain is typically associated with higher costs either through better and more precise manufacturing methods and processes or increased efforts in quality control; hence, accepting the existence of uncertain and dealing with it rather than trying to eliminate it makes products more affordable and production of those products more cost-effective.

Probabilistic design can be used to determine the effect of one or more variables on the outcome of the analysis. In addition to the probabilistic design techniques available, the ANSYS program offers a set of strategic tools that can be used to enhance the efficiency of the probabilistic design process.

2.5.2 Probabilistic Design System

ANSYS Probabilistic Design System (PDS) is a very powerful tool to solve probabilistic problems. As such, it can be used for an uncertainty analysis or a reliability analysis. It is tightly integrated into ANSYS, using the same graphical user interface, hence having the same look and feel as ANSYS itself. The PDS is based on the ANSYS Parametric Design Language (APDL), which allows users to parametrically build a finite element model, solve it, obtain results and extract characteristic results parameters such as the maximum deflection or stress etc. The PDS tools typically offer several

probabilistic methods (i.e. Monte Carlo simulation method and response surface method). The Monte Carlo simulation (MCS) method does not make any simplification or assumptions in the deterministic or probabilistic model. The key functionality of MCS techniques is the generation of random numbers with a uniform distribution from 0 to 1. The only assumption it does in fact make is that the limited number of samples is representative to quantify the randomness of the results parameters. With increasing number of samples the MCS method converges to the true and correct probabilistic result. The MCS is therefore widely used a benchmark to verify the accuracy of other probabilistic methods.

2.5.3 Distribution of Probability Design Variables

In a mass production filed, usually have a lot of data, in which case we could use commercial statistical tools that will allow us to actually fit a statistical distribution function that best describes the uncertain or scatter of the data.

The mean value and standard deviation are most commonly used to describe the scatter of data. The mean and the standard deviation of a set of data are use together. Frequently, information about a physical quantity is given in the form that its value is, for example, “100±5”. Generally, this form means that the value 100 is the mean value and 5 is the standard deviation. By definition, the standard deviation is the square root of the variance. It has the same units as the random variable and the mean; therefore, it is a better descriptor of dispersion or spread of either a sample of data or a distribution function than the variance.

In this study, Gaussian and lognormal distribution has considered as function for probabilistic designs input random variables. The Gaussian or normal distribution is a very fundamental and commonly used distribution for statistical matters. It is typically used to describe the uncertainty of the measurement data of many physical phenomena. Strictly speaking, every random variable follows a normal distribution if it is generated by a linear combination of a very large number of other random effects, regardless which distribution these random effects originally follow. The Gaussian distribution these random effects originally follow. The Gaussian distribution is also valid if the random

variable is a linear combination of two or more other effects if those effects also follow a Gaussian distribution.

2.5.4 Monte Carlo Simulation

Generally, MCS is applied to solving problems with complex uncertainty. Prediction of load-deformation of prestressed concrete beams behavior has inherent uncertainties due to concrete creep and shrinkage. A deterministic analysis, as presented in finite element modeling before is able to determine nominal prestessed concrete beams response. However, uncertainties in input variables cannot be avoided due to variability, vagueness and randomness in loads and resistances. Therefore, a probabilistic simulation is required to examine the response uncertainties.

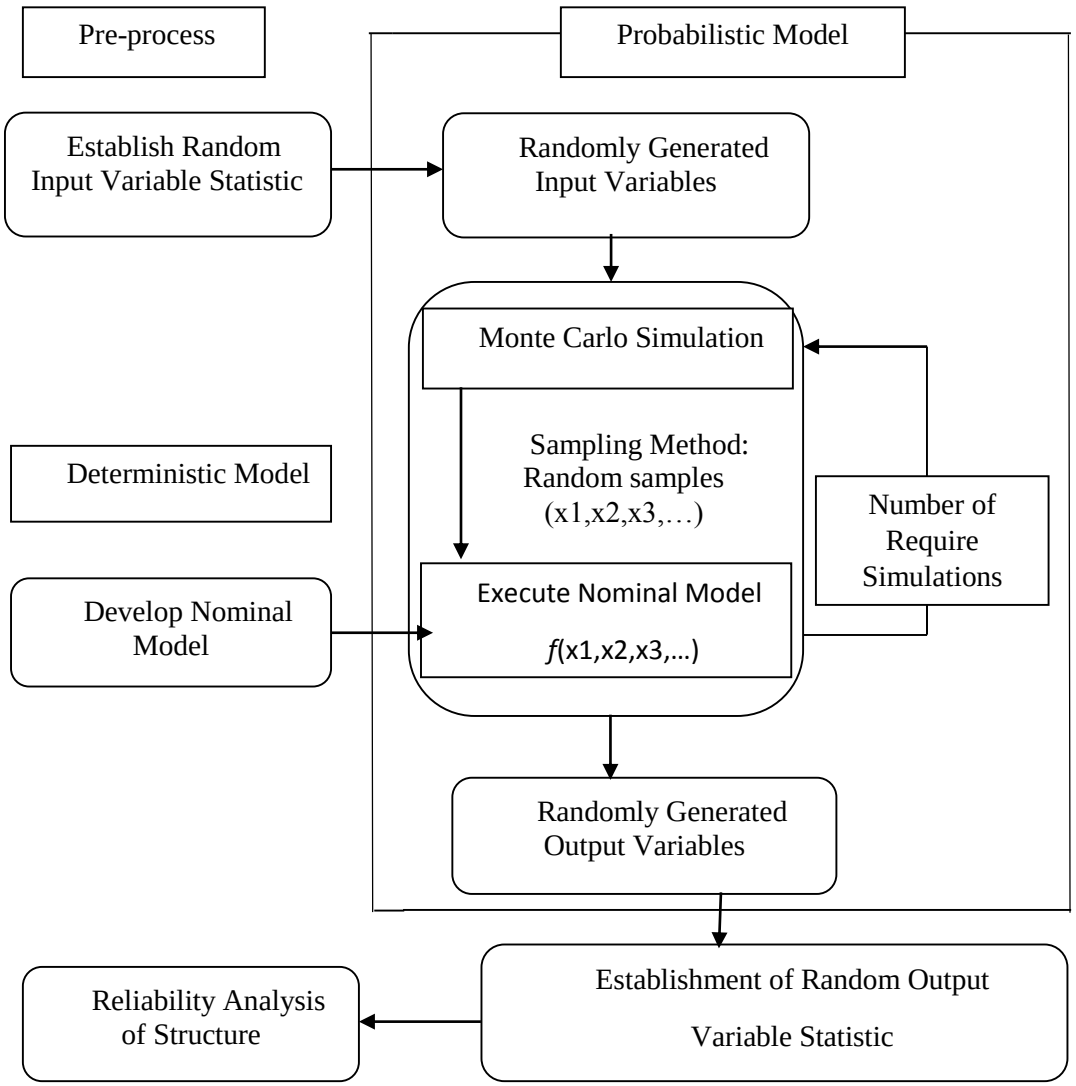

Figure 2.4: Probabilistic Analysis Procedures