STRUCTURAL CORROSION MODELING FOR RESERVE STRENGTH ASSESSMENT OF FIXED JACKET PLATFORM

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ABSTRACT

The response of a fixed offshore platform subjected to extreme wind and wave loadings (lateral loads) under corrosion conditions is studied. In this research the offshore jacket structures are modeled as a frame structures with fix-end condition since the foundation is using pile foundation. The performance of structure and will be checked using pushover analysis to get the performance level of structure during several response spectra of earthquake. The modeling and non-linear pushover analysis was done using SACS. The corrosion was applied on the structure and will be modelled in localized area based on inspection data. The performance of structure against non-linear pushover analysis is normalized as a capacity spectrum and three response spectrums were normalized as demand spectrum. Based on these curves the performance level of structures can be known and the differences between each response spectrums also shown in this research. Through the pushover analyses using SACS, the relation between time and residual strength was established and it was verified which zone had more corrosion influence to the jacket structure.

Key words: Pushover Analysis, Offshore Structures, Corrosion Modelling.


1. INTRODUCTION

Most offshore platforms are designated to operate for about 20 years. However, there are a lot of offshore platforms have been operating for more than their designated-life. After their designated-life has reached and there is an intention to utilize the offshore platforms for a few years more. Improvements in the possible oil recovery from several fields have increased the interest for using these facilities well beyond their initial design life [1]. Even if rather large
reconstructions, repairs and inspections have to be performed, the use of existing facilities beyond their design life will in many cases be economically preferable. In order to get an approval to do life extend, an under revised operating conditions, such as wells, modifications, and improvement will be done [2]. A major concern in this regard is that safety requirements should not be compromised.

Safety of structures is generally assumed to be obtained by design according to established standards and methods, often according to the limit state design, and for an expected design life. If a structure is intended to be used beyond its design life, a thorough control of the structural safety must be executed [3]. In particular this will be important with respect to fatigue and other continuous degradation mechanisms. Rules and regulations may have been slightly altered since the original design. Loads on offshore structures dominantly include environmental loads that can only be described by their statistical properties. The loading pattern (e.g. due to subsidence) and the environmental load may have changed, and the structure may have deteriorated to an unknown extent during decades in extreme weather [4]. Due to random changes in wind velocity and direction, the typical wave heights and periods also change randomly over time.

One of the most important thing to notice is the effect of existing corrosion. Corrosion is an important strength degradation phenomenon that is widely encountered in offshore structures as a result of harsh environment. It is generally accounted for as a uniform corrosion wastage [5]. The corrosion in marine structures, which are generally made of various grades of steel and low alloy steel, is often very severe, not only under a sustained immersed condition, but also under general exposure to atmospheric conditions [6]. Classified according to different initiation mechanisms, the corrosion in metals assumes various forms: "uniform, pit, crevice, impact, cavity bubble, and galvanic couple corrosion" [6]. The most common forms are the uniform corrosion and pit corrosion. The uniform corrosion is caused by the complete exposure of metal surface to corrosive media, and it spreads at about the same rate in all parts [5]. When uniform corrosion occurs, the structural strength can be estimated relatively easily by deducting the weight loss per unit area from original values. Corrosion can affect a lot of factors, especially the strength on the structure itself. Therefore, an investigation of strength assessment of the structure that takes into account the existing corrosion is very important before taking any decision regarding life extend.

2. LITERATURE REVIEW

Some researchers have conducted studies that analyze the effects of corrosion on steel structures offshore. A numerical study was carried by Engin Gucuyen and R. Tugrul Erdem to analyze the effect of corrosion attacks on structural behavior of jacket platform [6]. In this study, jacket platform was modelled based on finite element method (FEM) and composed of 3D solid tubular member. Then, the corrosion will make 10% weight loss (assumed by pitting corrosion) on the wall of tubular members. In another study, Abdul Haris [7] has developed a new approach to pre-dicting life of a fixed-jacked type offshore structure of which degradation effects related to corrosion, joint’s and clamp’s conditions, and marine growth are taken into consideration. The results of model analysis will be verified with vibration measurement of structure elements. In another study, Rahgozar [8] developed residual capacity curves of corroded I-section on the basis of thickness reduction. Corrosion on the lower flange and on the web was assumed. The effect of localized corrosion on plate buckling was investigated by Sadovsky and Drdacky [9]. The influence of pitting corrosion on the hold frames of bulk carrier was extensively analyzed by Nakai et al. The research of Heinemeyer and Feldman [10] focused on the influence of the corrosion on riveted connections. Angle section members, which are investigated in this study too, were previously analyzed by
Beaulieu et al. [11]. The specimens were corroded by galvanic process and the tests results were compared to the analytical results which were calculated according to Canadian and American standards. In the test set-up, eccentric compression was applied by gusset plate.

3. ANALYSIS APPROACH

3.1. SACS Approaches

The program used in this research is SACS which is based on finite element method (FEM) modeling, the phase of modeling and pushover analysis using non-linear static analysis. This software has the ability to offer a wide array of analysis and design to its user and generally could solve the finite element analysis from a simple two-dimensional frame to complex three-dimensional frames. This software is also able to solve non-linear static analysis and report the structural responses caused by wind, sea waves, and other related loads. One of the important features of this module is analysis by considering the large deflection, elastic-plastic and nonlinear finite element system for structures [12].

3.2. Finite Element (FE) Model

As shown in Figure 1, is the subject of this study. As pointed out in other studies, the splash zone, the area immediately above and below the mean water level, has long been a major concern for corrosion. In this study, corrosion was assumed on the jacket horizontal and diagonal brace(s) near the sea surface. Different length, thickness reductions and location were considered. A nonlinier push-over analysis was carried out for two different conditions; with and without corrosion. Comparison was made between the two cases to quantify the effects of corrosion on the strength/resistance of the jacket platform to extreme wind and wave conditions.

![Image](image_url)  
**Figure 1** Jacket platform showing illustration of corrosion near sea surface
As shown in Figure 2, it was assumed that only diagonal and some of horizontal brace experiencing corrosion near sea surface area. In analysis, a lateral force was applied until the platform reached its limit state (failure).

3.3. Pushover Analysis

The procedure is an incremental-iterative solution of the static equilibrium equations. The forcing function is a set of displacements or forces that are necessarily kept constant during the analysis. During an increment the resistance of the structure is evaluated from the intimal equilibrium conditions and the stiffness matrix is updated under certain conditions dependent on the iterative scheme adopted [12]. At convergence, the stiffness matrix is necessarily updated and another increment of displacements or forces is applied. The solution proceeds either until a pre-defined limit state is reached, or the program fails to converge.

The purpose of pushover analysis is structural analysis which considering nonlinear behavior of structural component due to material nonlinearity, effects of geometry nonlinearity, and cracking. This type of analysis of the structures has become increasingly important in the study of structural response to hazardous loads or increasing loads. In recent years, pushover analysis has been used for several engineers and the requirements of structural analysis have become more challenging. There are some reasons why this analysis is necessary to do [13]:

- New approaches to design of the structures for earthquakes and other hazardous loads which are based on structural response and using fragility functions some measures of structure’s performance. Those fragility functions and quantification is carried out to define the performance limit state that describing the condition of the structure in relation usability and safety. Often, the limit states used in special designs are well beyond linear elastic behavior, in many cases approaching collapse conditions.

- Areas in the structures that are low to moderate seismicity have traditionally been designed for gravity loads. Evaluation such structures under more severe loads prescribed by modern codes which requires estimation of their strength and ductility reserves at various levels of ground motion.
3.4. Corrosion Data Input

For this strength assessment of existing fixed offshore platforms, corrosion will be modeled by the decrease of thickness and the size of corroded area on the structural members. This information can be identified based on the inspection report.

4. ANALYSIS RESULTS

In this study, there are six corroded parts that will be modelled on tubular member of the jacket. Five of the member are jacket legs of the structure and one member is horizontal brace of the structure. Figure 2 shows the areas where there are existing corrosions on the structure. The diameter of brace is 14 inches and there are four cases were considered with thickness difference which is decreased due to corrosion (shown in table 1).

<table>
<thead>
<tr>
<th>Cases</th>
<th>Description</th>
<th>Structural Thickness of Corroded Area (meter)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Horizontal Brace</td>
</tr>
<tr>
<td>Case 1</td>
<td>No Corrosion</td>
<td>0.009347</td>
</tr>
<tr>
<td>Case 2</td>
<td>50% thickness left</td>
<td>0.004674</td>
</tr>
<tr>
<td>Case 3</td>
<td>25% thickness left</td>
<td>0.002337</td>
</tr>
<tr>
<td>Case 4</td>
<td>10% thickness left</td>
<td>0.000935</td>
</tr>
</tbody>
</table>

While for the size of the corroded area are modelled in three different area dimension such as the length of the corrosion that happen on the tubular members. The three cases of corroded area shown on table 2 and is illustrated in Figure 3.

<table>
<thead>
<tr>
<th>Cases</th>
<th>Structural Corroded Length (meter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 4</td>
<td>5.951</td>
</tr>
<tr>
<td>Case 5</td>
<td>5.037</td>
</tr>
<tr>
<td>Case 6</td>
<td>6.865</td>
</tr>
</tbody>
</table>

Then, Figure 4 presents the deflected shapes of the platform at limit state of the platform at limit state of all the cases. In this figure, it shown that the bigger area of the corrosion, the more damage will happen on the platform Therefore, the Reserve Strength Ratio will decrease.
Structural Corrosion Modeling for Reserve Strength Assessment of Fixed Jacket Platform

if the corroded area size is increasing. Meanwhile, it shown that the thickness degradation of the tubular member can affect the response of the structure. Figure 5 summarizes the RSR for all the cases.

<table>
<thead>
<tr>
<th>Cases</th>
<th>Description</th>
<th>RSR (percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>No Corrosion</td>
<td>100</td>
</tr>
<tr>
<td>Case 2</td>
<td>50% thickness left</td>
<td>70</td>
</tr>
<tr>
<td>Case 3</td>
<td>25% thickness left</td>
<td>69</td>
</tr>
<tr>
<td>Case 4</td>
<td>10% thickness left</td>
<td>69</td>
</tr>
<tr>
<td>Case 5</td>
<td>Length 1</td>
<td>70</td>
</tr>
<tr>
<td>Case 6</td>
<td>Length 2</td>
<td>66</td>
</tr>
</tbody>
</table>

Figure 5 RSR graph on different cases

5. CONCLUSIONS

It can be concluded that from this research about non-linear behavior of jacket structure in offshore platform can be conducted with adequate data of earthquake that occurred around the location of offshore platform. From this research several conclusions as follows:

- The evaluation of non-linear pushover analysis in offshore platform need to be performed to ensure the Reserved Strength Ratio (RSR) is still adequate. This is also functioning for the life time remaining study if the offshore platform is old and still need to be used.
- By using non-linear pushover analysis, we can set the performance level so we can ensure that our offshore platform condition is still at good shape without any sufficient damage when the earthquake occurred.

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