Corrosion modeling for condition assessment of offshore jacket Leg for life extension

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by

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the

Civil Engineering Department

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In partial fulfillment of the requirement for the

BACHELOR OF ENGINEERING (HONS)

CIVIL ENGINEERING

Approved by:

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UNIVERSITI TEKNOLOGI PETRONAS

BANDAR SERI ISKANDAR, PERAK

September 2016

CERTIFICATION OF ORIGINALITY

This is to certify that, I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained here have not been undertaken or done by unspecified source or persons.

…………………………..

Mbikoyesu Moses Poulino

ABSTRACT

As structures age, their structural reliability to sustain operations becomes a crucial issue, especially in the oil and gas industry. In this study, corrosion a critical issue to their performance has been studied. The main parameters of size and location of localized corrosion attack has been extensively analysed with the aid of Finite Element Analysis (FEA) software, ANSYS workbench. The corrosion is represented as an elliptical cut on the surface of the leg. The study focuses on the outcome obtained for Von-Mises stress and deformation on application of the pushover analysis on varying loads. Von-Mises stress basically predicts the yielding of the material stress on application of environmental loadings; meanwhile the structures deformation defines the change in shape of the structure. The results obtained indicates that corrosion causes higher stress at the areas closer to the joint supports as compared to the mid of the section.

ACKNOWLEGMENT

In completion of my Final Year Project (FYP), I would wish to extend my utmost gratitude to those who directly or indirectly contributed towards its goal attainment. This has made a great milestone to my career as a graduate Civil and Environmental Engineer.

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CHAPTER 1

1.0 INTRODUCTION

1.1 *Background of study*

At present, Malaysia's oil and gas facilities comprises of about 200 fixed offshore jacket platforms of which 60% are have been operational for more than the last 20 years 20% estimated to have foregone 30 years with majority subjected to ravages of time (Kurian et.al, 2014). On global perspective, two-third of aging platforms still works for 5 to 10 years after their design period (Tan et.al., 2016). It is imperative to note that offshore structures are subjected to adverse environmental loading condition (wave and current loadings) as well as degrading occurrences such as corrosion and fatigue cracking. Inlight of the above, asset inspection, repair and maintenance has been a crucial tool in the oil and gas industry to ensure structural reliability of the structures in question inorder to enhance the future production of the recoverable oil.

The general operations of the offshore production facilities in Malaysia require highly technical and economical engineering solution. Strength assessment of structures in account of corrosion Phenomena is a significant tool in preparation of the platform's operations. Corrosion attacks on the jacket structures have been a serious problem extensively leading to worse conditions of work on the offshore platforms.

This study provides an assessment to the consequence of corrosion effect to the strength of a one member leg of a jacket platform under severe wave and current loadings. Pushover analysis using a package of finite element model ANSYS is utilized. The pushover analysis is conducted to quantify the Reserve Strength Ratio (RSR), a structural reliability measurement tool. The following parameters are considered in this study: (i) Size of corrosion (ii) Location of corrosion. These parameters will be used to analyse the structural response of the jacket leg member.

1.2 *Problem statement*

Majority of the oil platform structures in Malaysia will soon be exceeding their design life. As such, asset management has become a more significant issue considering the need to maintain the strength structural reliability to facilitate extraction of existing and recoverable oil resources. The jacket platform structures are continuously subjected to severe environmental loadings (wave and current) as well as constraints of corrosion. This study focuses on assessing or evaluating the influence of corrosion on the design strength of one member jacket leg. The prime hypothesis of this study is that, size and location of the corroded surface would extremely compromise the structural integrity of the platform structure for lifetime extension. This study only focuses on analysis of a single leg of the platform; results obtained could be translated on how the overall platform structure could be impacted on corrosion attack.

1.3 *Objective*

The aim of this project is to determine the effect of corrosion on the strength of an existing ageing Jacket leg member. In order to achieve this, the study will be focused to the objectives below;

1. To study the variation of corrosion (size and location) on the offshore jacket leg.

2. To evaluate the effect of corrosion on the structural performance of the offshore jacket leg.

1.4 *Scope of study*

Considering the major implication of corrosion such as loss of design strength of the structure under study, consideration on size and location of corrosion on the structural members is analysed. A one member jacket leg of the offshore jacket platform is used in this study. Its structural modeling performed and then corrosion applied at three distinctive locations. Von-Mises stress values and deformation recorded and analysed respectively.

The leg is fixed at one end, compressive force applied in the negative Z direction of the global axis and an arbitrary assumed uniform distributed lateral loadings applied in the negative Y-direction on isometric view. Figure (1) shows the bottom view of the described structure.

. This analysis determines the ultimate capacity and showcases the global instability of the jacket platform. The targeted areas under study are the top, mid and bottom (to the fixed) part of the leg member.

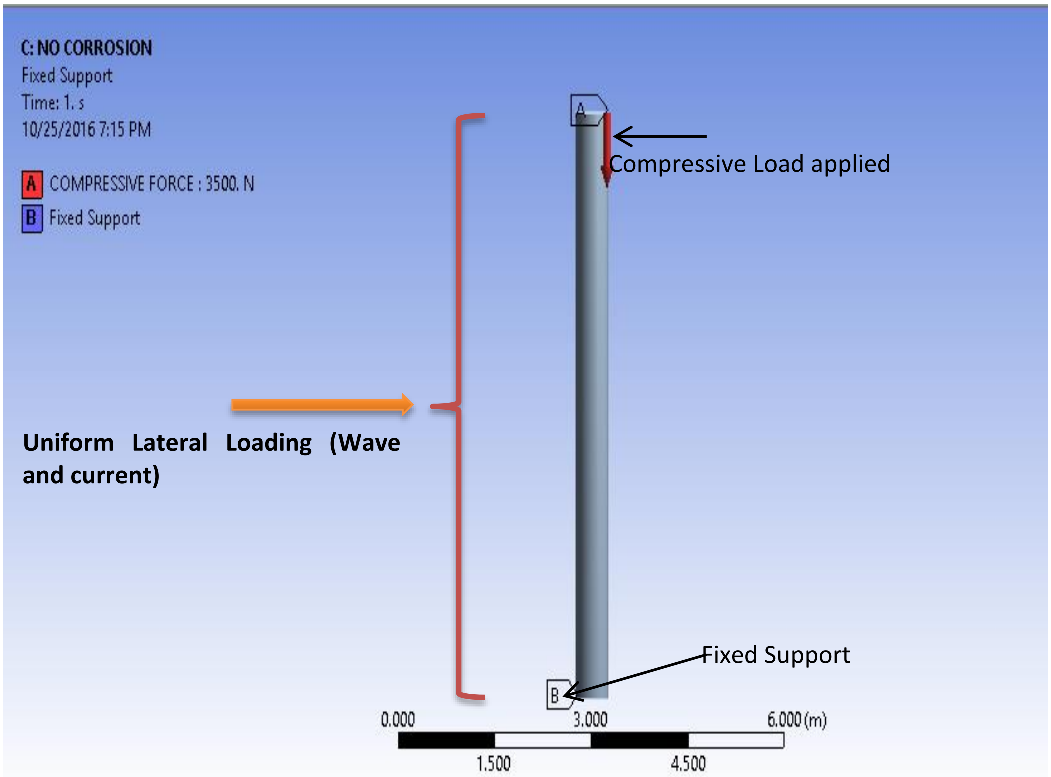


Figure 1. Bottom View of the Jacket leg under study, fixed at one with load application

In this study, Reserve Strength Ratio (RSR) is used to determine the ability of the structure to withstand the excess loads as indicated in Equation 1 and 2 below. This is used to maintain or extend the ageing life of the platform (Kurian et.al, 2014)

$$\text{Reserve Strength Ratio} = \frac{\text{ultimate Strength}}{\text{Design Strength}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where:

$$\text{Design Strength} = F_{wave} + F_{current} + F_{deck} + F_{wind} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

F_{wave} = Wave Load
$F_{current}$ = Current Load
F_{deck}= Load on the deck
F_{wind}= Wind Load (Neglected in this study)

Static loadings iterated to determine the reliability of the leg structure in this study are assumed by considering loads that do not cause the structure to exceed its yield value (250Mpa) as shown in Table 6.

Lastly comparison is conducted on the conditions of corrosion effect at the top, mid and near to the joint support of the leg member inorder to evaluate the effect of corrosion on the behavior of the structure.

CHAPTER 2

2.0 LITERATURE REVIEW

Today, the oil and gas industry is one of the fastest growing and income generating especially to the Malaysian economy. Despite of a few technical and management problems globally witnessed in the industry (Zve et.al, 2015), Continues innovations are exerted to improve the reliability and strength of its structures aiding continuous production. Majority of the structures are aging (Kurian et.al., 2014) in addition to degrading anomalies such as corrosion and fatigue cracking which has been researched extensively for the past years. Corrosion attacks any component of the structure with different size extensions and seldom attacks the whole structural member (Sari et.al, 2016). There are quite a number of causes of corrosion. A few are discussed below:

a. The pH of the water

The pH scale ranges from 0-14 with its neutrality at 7. Below 7, represents the acidity of the water whereas above 7 represents its alkalinity state. This is based on the logarithmic advancement like the one commonly used by “Richter” scaling for earthquake measurement. Therefore when the pH of the water is above the point of neutrality, for example 8, a corrosion protective oxide film is usually formed on the pipe walls. Whilst when pH is below neutrality (acidic), the barrier thus gets eroded, hence subjecting the pipe support to corrosive effect of the water.

b. The amount of oxygen in the water

Sea water is an open water system and is often filled with oxygenated water. Oxygen comprises of 30% dissolved air in water with the remaining percentage mostly to nitrogen. This percentage of oxygen erodes metal surface through electro-chemical process by internal oxidation. The jacket steel metal surfaces ions diffuse into the sea which acts as an electrolyte. This causes reaction with oxide and hydroxide. As a result of high oxygen concentration at sea surface, a greater potential of corrosion attack is imposed to the structural members. Pits are formed at the metal surface as well as at the joints. Overtime, high stress is generated along the mentioned formations leading to fractures and breakage. High water temperatures and pressures lowers amount of oxygen in the water. This however, speeds up the oxidation process. Vast research conducted shows that corrosion occurrences are high temperate water bodies, hence is Malaysian case.

c. The chemical makeup of water

Sea water has variety of dissolved minerals. The combination of the dissolved minerals and the chemical property of the sea water have differing effects on the actions of corrosion. For instance, moderate to high proportion of calcium aids as a protective coating on the pipe while its higher levels may cause its build up in the pipe. Corrosion as a result of chemical makeup of the sea water is caused by Hydrogen Sulphide (H_2S), Carbondioxide (CO_2) and strong acids such as Nitric acid (HNO_3) and Sulphuric acid (H_2SO_4).

Admitting that a few traditional approach in which global loads are applied to individual components and evaluating their resistance for designing offshore jacket platforms (Xie, 2012) still exist today, a good number of Finite Element Model software are used aiding this process. ANSYS workbench is a lighter Finite Element tool which has no mesh control; hence it is suitable for quick analysis.

Acknowledging a number of researches, investigation was conducted on the ultimate strength capacity of corroded steel plate under in-plane shear loads (Paik et.al, 2004). Results showed decrease in the ultimate strength of the element regulated by the degree of pit corrosion intensity (DOP) which connotes the percentage ratio of corroded surface area to the original surface. In addition to the same study, results revealed that ultimate shear strength of pitted corrosion could be calculated by the given formula;

$$R_T = \frac{T_U}{T_{Uo}} = \begin{cases} 1.0 & \text{for } \alpha \leq 1.0 \\ -0.18\text{in}\alpha + 1.0 & \text{for } \alpha > 1.0 \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ (3)$$

Where:

R_T is the ultimate shear strength reduction factor; T_U is the ultimate shear strength for the pitted tube, T_{Uo} is the ultimate shear strength for an intact (uncorroded).

and α= DOP. The higher the degree of pit corrosion intensity, the lower the ultimate strength of the structure (Nakai et.al, 2004).

Pit corrosion is more destructive and insidious with its localized form of attack of structures (Anto, 1999). However, they are hard to identify due to their small sizes.

Similar study was conducted by Sadovsy and Drdacky, (2000). They investigated the influence of pitting corrosion on a buckling plate subjected to localized corrosion using a numerical study. It was noted that corrosion mass loss, location and modulus of elasticity were less significant in influencing the ultimate design strength except for the thickness reduction. Recent research (Sari, et.al., 2016) proved thickness of the corroded element including its size are more sensitive to the Reserve Strength Ratio (RSR) than corrosion location.

In another study, Rahgozar, (2008), an investigation was conducted to review the impact of uniform corrosion on a steel structure. Beams were analysed by accessing their remaining capacities in-regard to bending stresses, shear failure, lateral torsional buckling and bearing failure. Residual capacity curves for I-section beams were plotted on the criteria of thickness reduction. It was found out that loss of thickness by corrosion reduces the structure's capacity, change mode of failure as well as alteration in the class of the structural elements, for instance from plastic to semi-compact. This finding on the impact of thickness reduction to the structural integrity of a structure confirms to (Sari, et.al, 2016), Sadovsy and Drdacky, (2000).

Zve, et.al, (2015), investigated the effect of zoning corrosion on the life-time structural reliability of a jacket offshore structure using a refined model for predicting the progression of corrosion with time and of material losses in the zonings. Displacement of structures subjected to loadings aided the evaluation of corrosion on the jacket platforms. Like a few research findings, it was also found that the structure's global stiffness was affected by the uniform thickness loss.

Salau, et.al, (2011), conducted a reliability assessment of offshore jacket structure in Niger Delta. Reliability of the structures was noted to a product of bracings and legs and the value decreases as the platform is aging.

Conclusively, limited research in relation to the effect of corrosion on jacket platform structures has been conducted. Therefore, this project will focus on a comprehensive structural analysis that will help to address the strength reliability of the jacket leg structure subjected to different corrosion situations. Hence, helping to reach a sustainable decision to the life extension of the jacket platform structure.

CHAPTER 3

3.0 METHODOLOGY

Some rational assumptions on study parameters; corrosion elliptical shaped size having a constant thickness and its respective location variation are made. A portion of the jacket leg, Figure 1, was used in evaluating the impact corrosion would cause to the whole structure. Various lateral loadings are applied to the structure. On application of the pushover analysis, respective values of leg's displacement and Von Mises stress are recorded. Detailed step used to achieve the results is as shown in Figure 4.

3.1 *Structure model*

The structure is a steel with density of 7850 kg/m^3, yield strength $2.5x10^8$ Pa, Compressive strength $2.5x10^8$ Pa, Tensile strength $4.6x10^8$ Pa is designed under assumption that it is fixed at one end and the other end subjected to gravity load. The structure is of height 6.75m, Outer Diameter (OD) of 0.49m and Inner Diameter (ID) of 0.47m. The leg structure's mass is 799.03Kg (7838.4843N). 40% (3135.39N) of the self-weight is assumed to act as gravity load (concentrated) on the structure.

Pushover analysis is performed on the corroded leg member with varying loads until ultimate strength of the structure is recorded on a Graph of load against displacement.

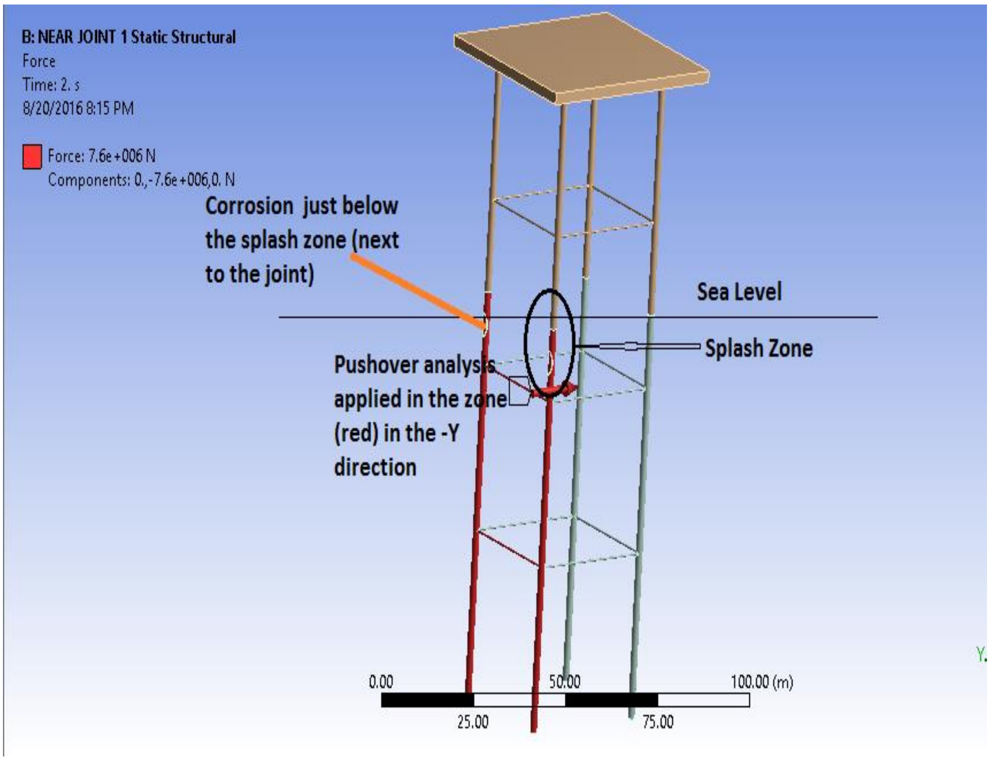


Figure 2.Structure Model showing corrosion

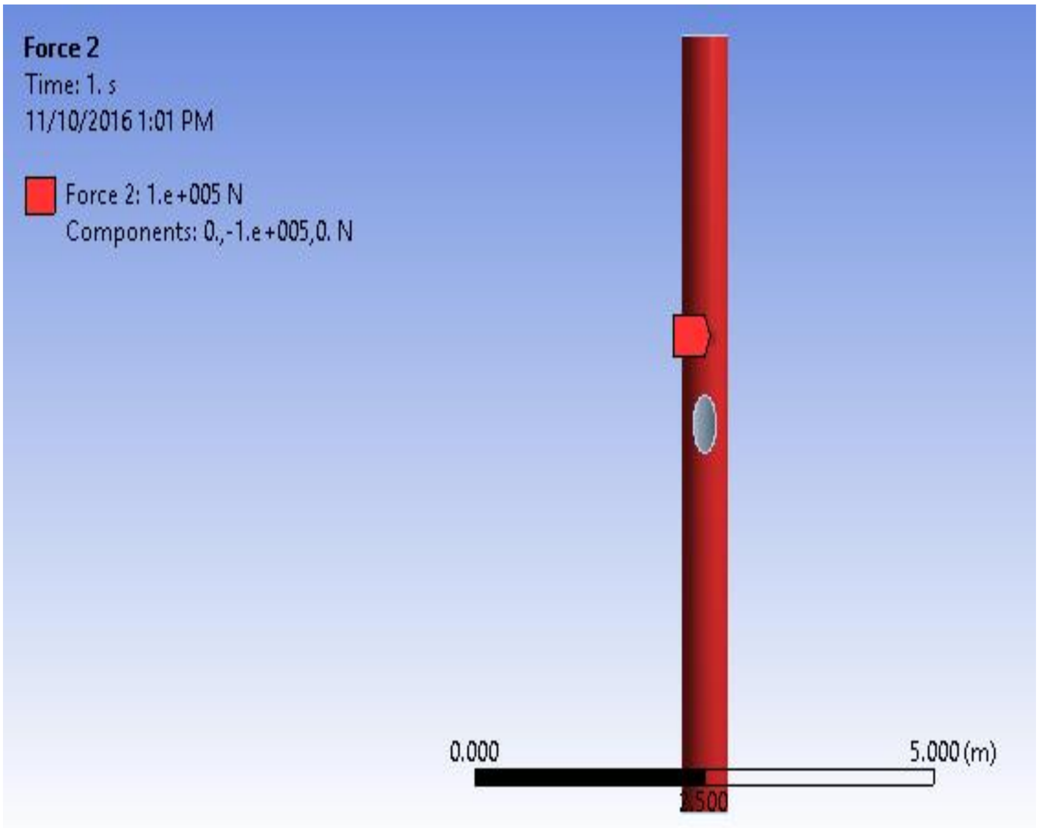


Figure 3. Corroded Leg member of the jacket perform under study

3.2 *Description of the Numerical Model*

The intact model consists of 3200 nodes and 450 elements per unit area with an optimum fine mesh size of 0.15m. The mesh size was obtained on performing a mesh sensitivity analysis described below. Mesh sensitivity analysis aids in determining the most appropriate mesh size inorder to achieve the accurate result when using the FEM. Besides that, the type and size of the element also affects the accuracy. The higher the mesh density, the accurate the result. However applying high density mesh would require a large size of computer memory and takes long to obtain result. It should also be noted that accuracy of the results for any FEA depends on the inputs of the geometry, material properties, boundary conditions and analysis settings. ANSYS workbench provides standard measure value for material in study.

3.2.1 Geometry Meshing

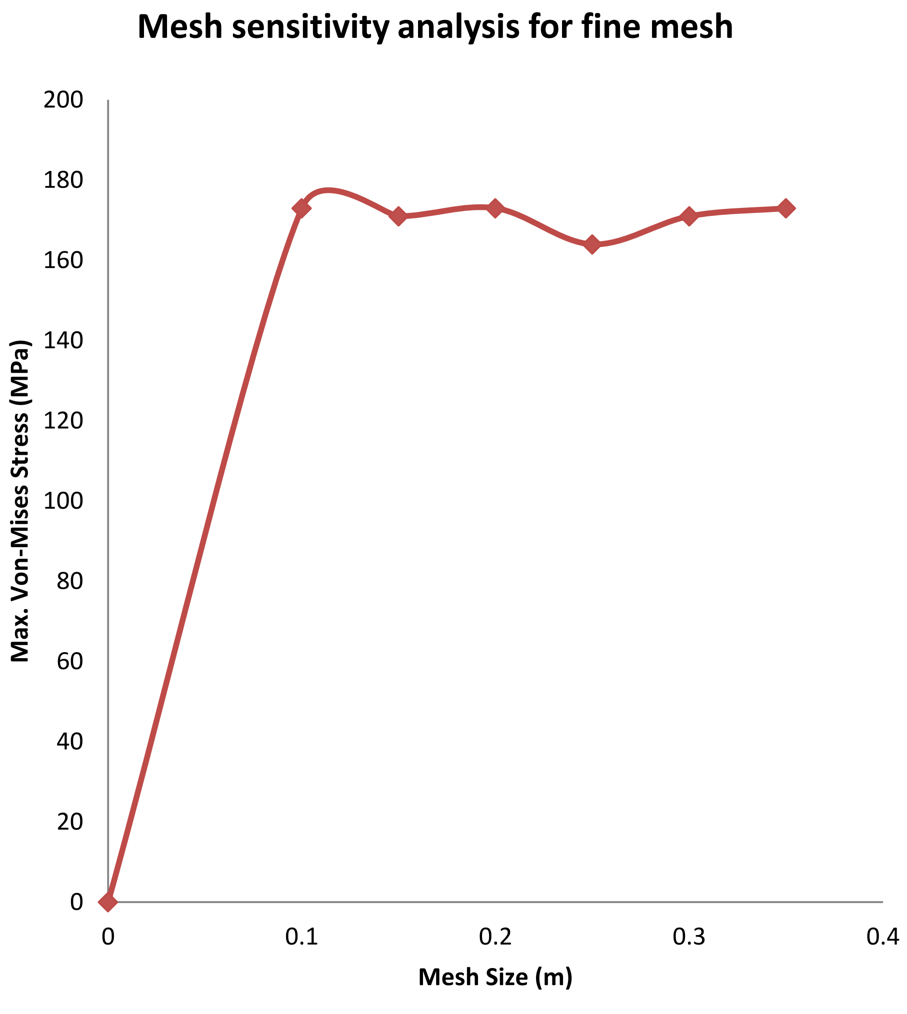
Different fine, medium and coarse mesh sizing were refined by applying a lateral static loading of 80KN (Table 1, 2 and 3). The respective maximum Von-Mises stress values of the structure are plotted in Graphs 1, 2 and 3 below. Mesh sizing incremented by 0.05m for each iteration shows that stress values obtained are almost constant. In this study, meshing quality selection was based on ensuring the meshing quality standard (>0.0001) and the Jacobean ratio (<40). Mesh obtained for the 0.15m mesh size were 0.32 and 1.97 respectively in conformity to the standard meshing on using ANSYS workbench.

3.2.1.1 Fine meshing

Mesh Size (m)	Max Stress (MPa)
0.1	173
0.15	171
0.2	173
0.25	164
0.3	171
0.35	173

Table 1. Table of values of various fine mesh sizing and their respective max. Von-Mises stress

The Graph 1 below shows that increase in the mesh sizing reduces the accuracy of the Von-Mises stress value of the structure. However, further increase in mesh sizing causes minor change to the stress results of the structure. Increase of the size from 0.1 to 0.15 causes about 1% change in stress.



Graph 1. Graph of Fine mesh sizing against Max Deformation

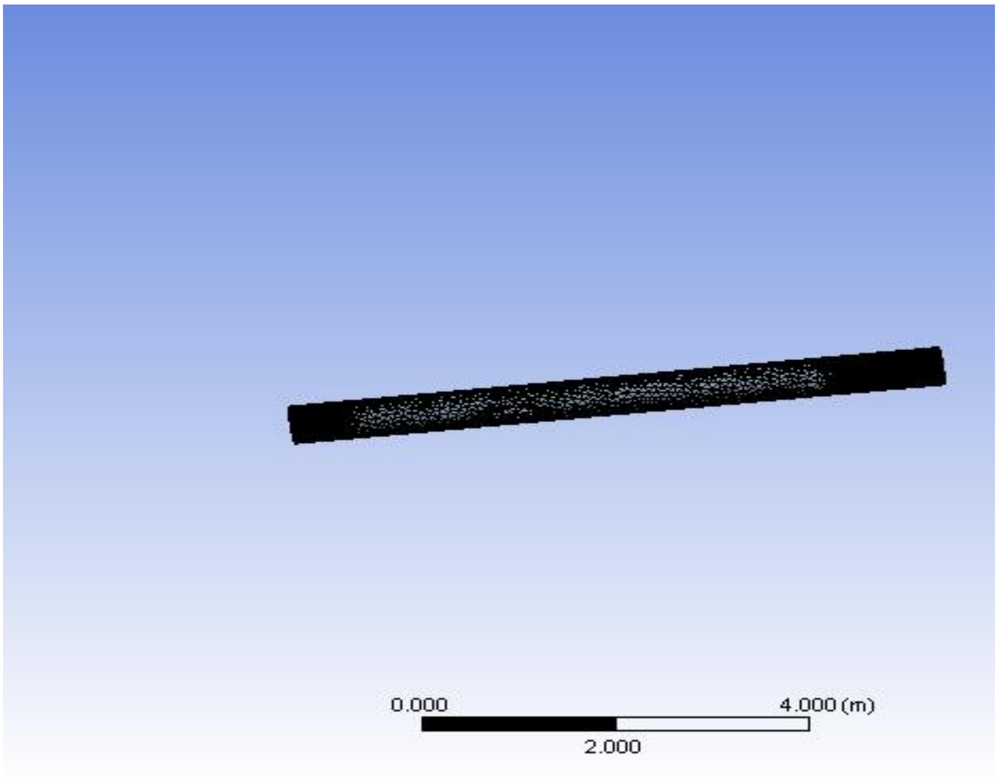
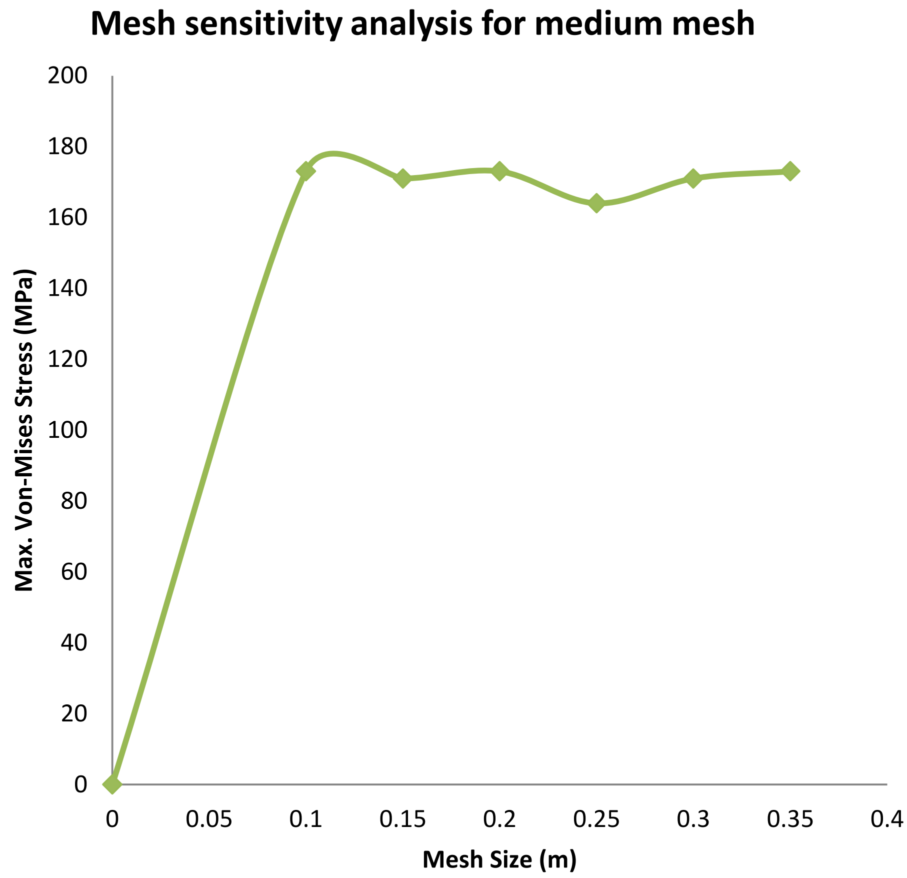


Figure 4. Fine Meshed jacket leg.

3.2.1.2 Medium Mesh Sizing

Mesh Size (m)	Max Stress (MPa)
0.1	164
0.15	151
0.2	166
0.25	169
0.3	168
0.35	167

Table 2. Table of values of various Medium mesh sizing and their respective max. Von-Mises stress



Graph 2. Graph of Medium mesh sizing against Max Deformation

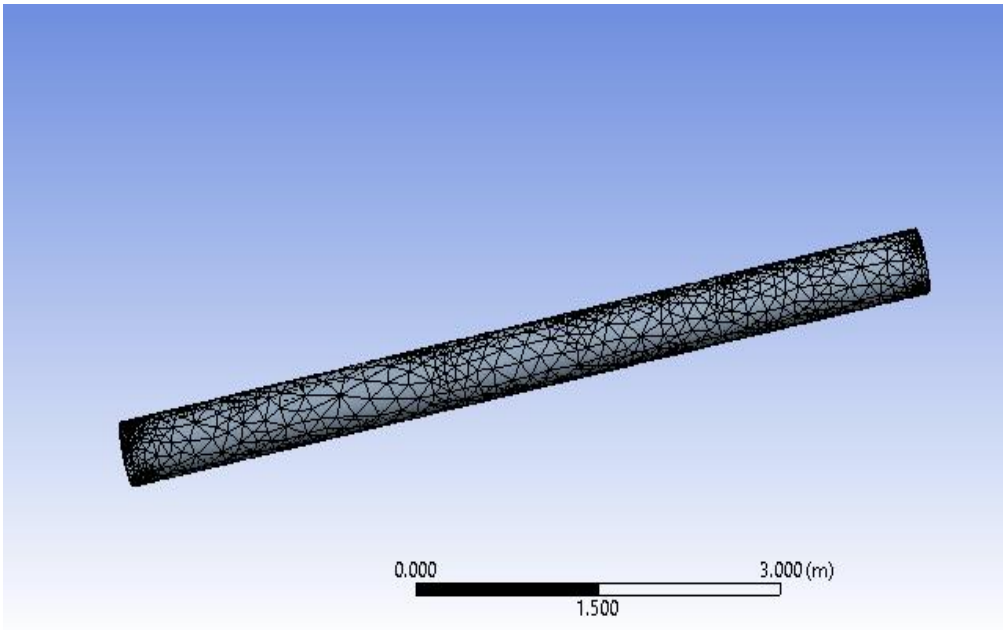
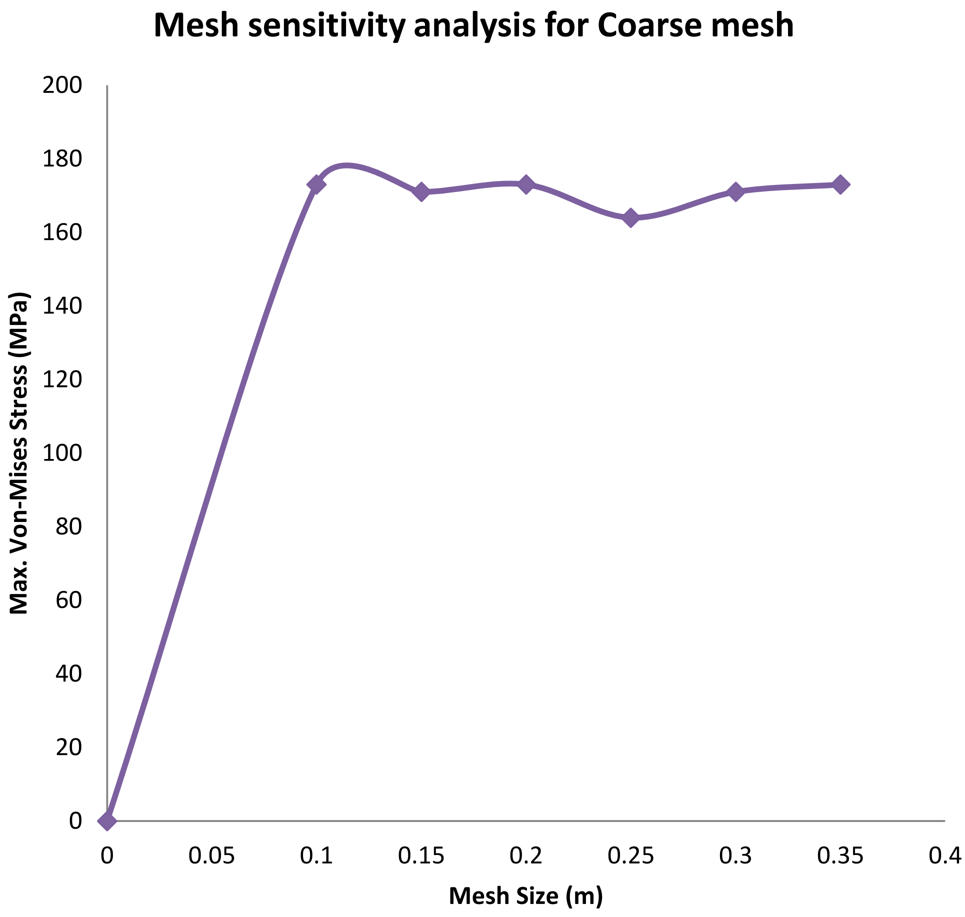


Figure 5. Medium Meshed jacket leg.

3.2.1.3 Coarse Mesh Sizing

Mesh Size (m)	Max Stress (MPa)
0.1	164
0.15	151
0.2	165
0.25	156
0.3	159
0.35	151

Table 3.values of various Coarse mesh sizing and their respective max. Von-mises stress



Graph 3. Graph of coarse mesh sizing against Max Deformation

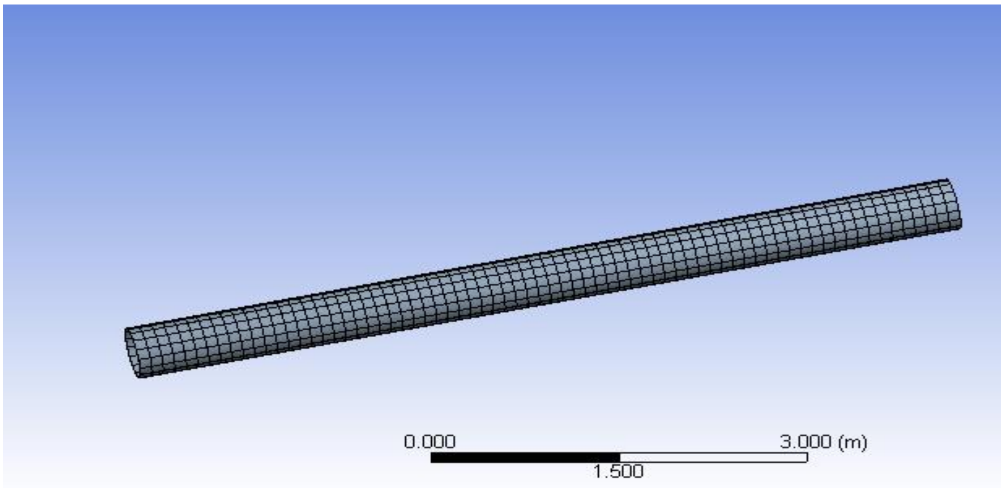


Figure 6. Coarse Meshed jacket leg .

After running the mesh analysis, the result obtained is as in Figure (4). Fine meshing is more appropriate as it aids numerical model to achieve the accurate output of the analysis.

3.3 *Model Dimension*

The length of the jacket leg is 6.75m, 0.49m in diameter, 0.02m inner thickness as adopted (Nazari, M. et al). Corrosion is assumed as an elliptical shaped cut, Figure 5 below. In the analysis shape size is reduced by 50% to determine its variation and while varying its location at the top, mid-point and lower end (next to the fixed joint) respectively.

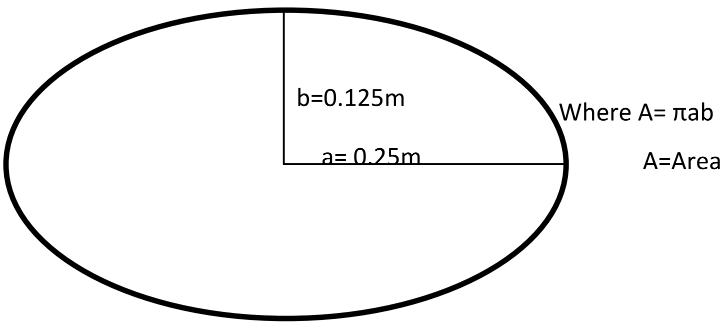


Figure 7. Surface Estimation of the corrosion

Figure 8. Corrosion on a typical Jacket Leg Surface

The dimensions used in this study are of scaled members of a fixed jacket platform as shown in the Table 4 below. A ratio of L/D is equal to the actual most common tubular members used in the industry.

L(m)	D (m)	L/D	Corrosion size(m^2)
6.75	0.47	14.362	0.0982
6.75	0.47	14.362	0.0491
6.75	0.47	14.362	0.0245

Table 4 Corrosion Size Variation

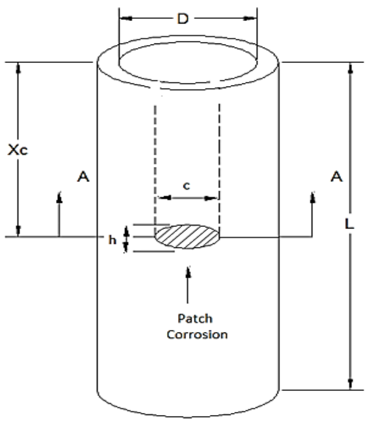


Figure 9 Geometry and the corroded Area

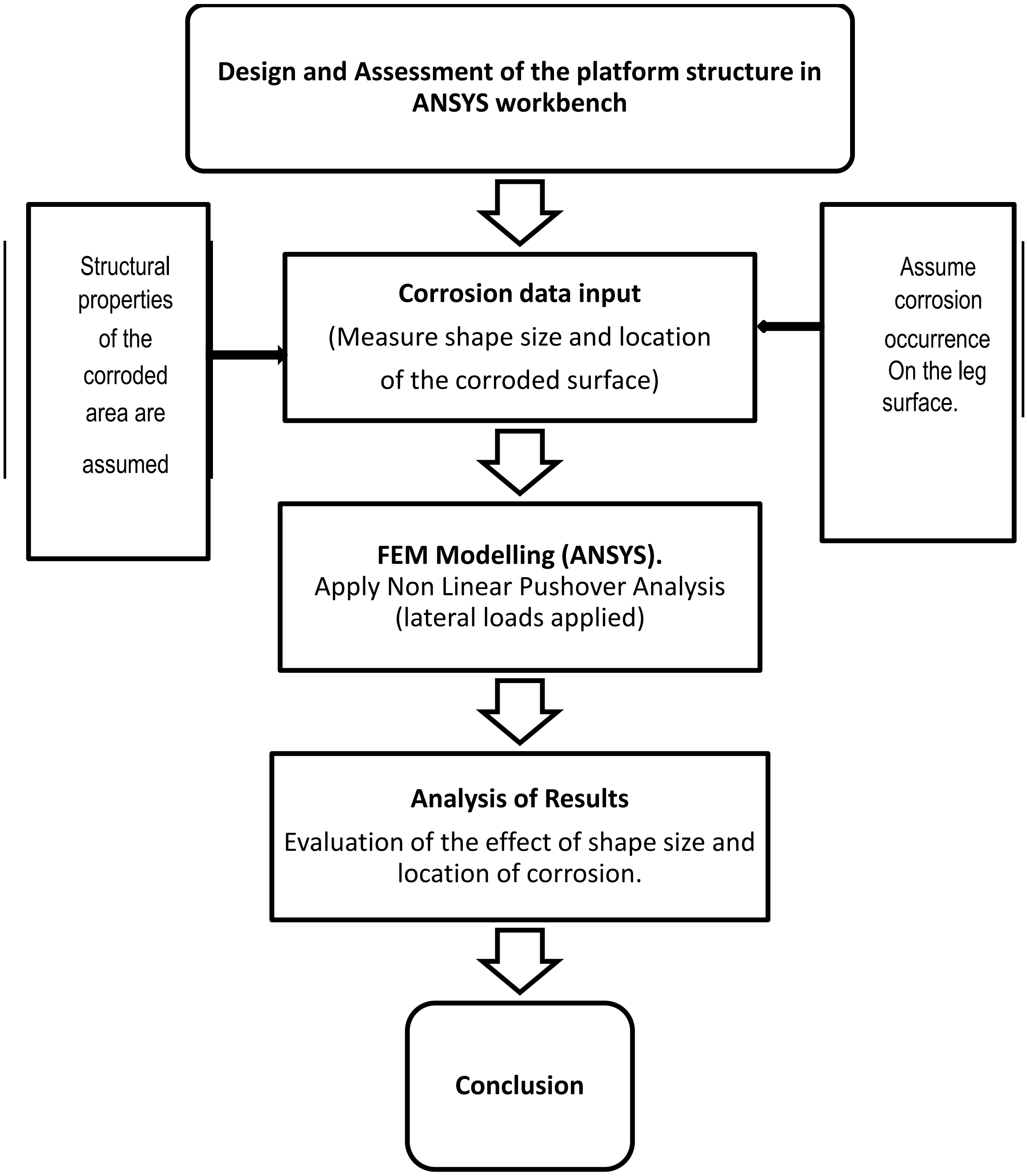


Figure 10. Flow chart showing Methodology of study

3.4 *Project Milestone*

PROJECT TASK	FINAL YEAR PROJECT 1														BREAK	FINAL YEAR PROJECT 2													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14		15	16	17	18	19	20	21	22	23	24	25	26	27	28
Planning and Research																													
Sampling and Data collection																													
Extended Report Submission/Proposal Defense/Interim Report																													
Simulation and Pushover Analysis																													
Results Interpretation																													
Final Report and Presentation																													

Table 5. Gantt chat for FYP 1 & 2

Legend

Colour	Definition
	Preliminary Research Work
	Design and Preliminary Results
	Simulation of more results data
	Evaluation of Overall final results
	Final Compilation of results

CHAPTER 4

4.0 RESULTS AND DISCUSSION

The result includes design specific output such as total deformation, equivalent (Von-Mises) stress and normal stress. Von-Mises stress predicts yielding of materials at given loading. It yields global principle stress results as well as the total deformation (global deformation) of the structure's response to the applied loading meanwhile normal stress is included to evaluate the structure's response to a directional loading.

Analyses of the nodes from the bottom of the pipe (fixed end) to the top (freely hanging) are presented.

4.1 *Stress Analysis*

4.1.1 Von-Mises Stress

The Von-Mises stress is derived from the distortion energy failure which compares distortion in actual case and simple tension. Literally, distortion occurs when distortion in actual case exceeds one in tension at failure.

Distortion energy for a three dimensional case is expressed as:

$$u_d = \frac{1+v}{3E}\left[\frac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}{2}\right] \quad \text{....... (4)}$$

Where;

E= Modulus of Elasticity

V= Void ratio

ρ = Density of steel material

Theoretically, equivalent Von-Mises stress is expressed as:

$$\left[\frac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}{2}\right]^{1/2}=\sigma_v \quad \text{........(5)}$$

where;

σ_v = Von-Mises stress

For a failure to occur; Von-Mises stress exerted on the material exceeds the yield strength of the steel material. Hence;

$$\left[\frac{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}{2}\right]^{1/2}\geq\sigma_y \quad \text{........ (6)}$$

Where σ_y = Yield strength of the material

Yield stress for the jacket leg under study is 250MPa. Therefore to ensure its reliability, static loadings applied laterally on the structure should not exceed the structure's yield strength (250Mpa) as in Table 6. Same values justified are used to analyse the impact of corrosion on the member leg. Result shows that Von-Mises stress is minimal at the top end of the pipe as compared to the area to the bottom. This confirms to the theoretical deduction that stress is high the location with minimum displacement and vice versa.

Steps	**Force (KN)**	**Max. Von-Mises Stress (MPa)**	**Max Total Deformation (m)**
1	100	189	0.044875
2	110	209	0.049363
3	120	228	0.053865
4	130	247	0.051859

Table 6. Without Corrosion

Steps	Force (KN)	Max. Von-Mises Stress (MPa)	Max Total Deformation (m)
1	100	198	0.045138
2	110	218	0.049653
3	120	238	0.054168
4	130	258	0.058684

Table 7. Corrosion at the top of the jacket leg

Steps	Force (KN)	Max. Von-Mises Stress (MPa)	Max Total Deformation (m)
1	100	204	0.04644
2	110	224	0.051084
3	120	244	0.055728
4	130	264	0.060371

Table 8. Corrosion at the mid of the jacket leg

Steps	Force (KN)	Max. Von-Mises Stress (MPa)	Max Total Deformation (m)
1	100	449	0.046954
2	110	492	0.051635
3	120	536	0.056314
4	130	579	0.060990

Table 9. Corrosion at the bottom of the jacket leg (towards the fixed joint)

Load is distributed load on the structure is linear from the top (free) end to the fixed end. As such, the large force concentrated at the bottom fixed end, acting at small area results into the stress results as observed in Figure 11, 12, 13 and 14 below.

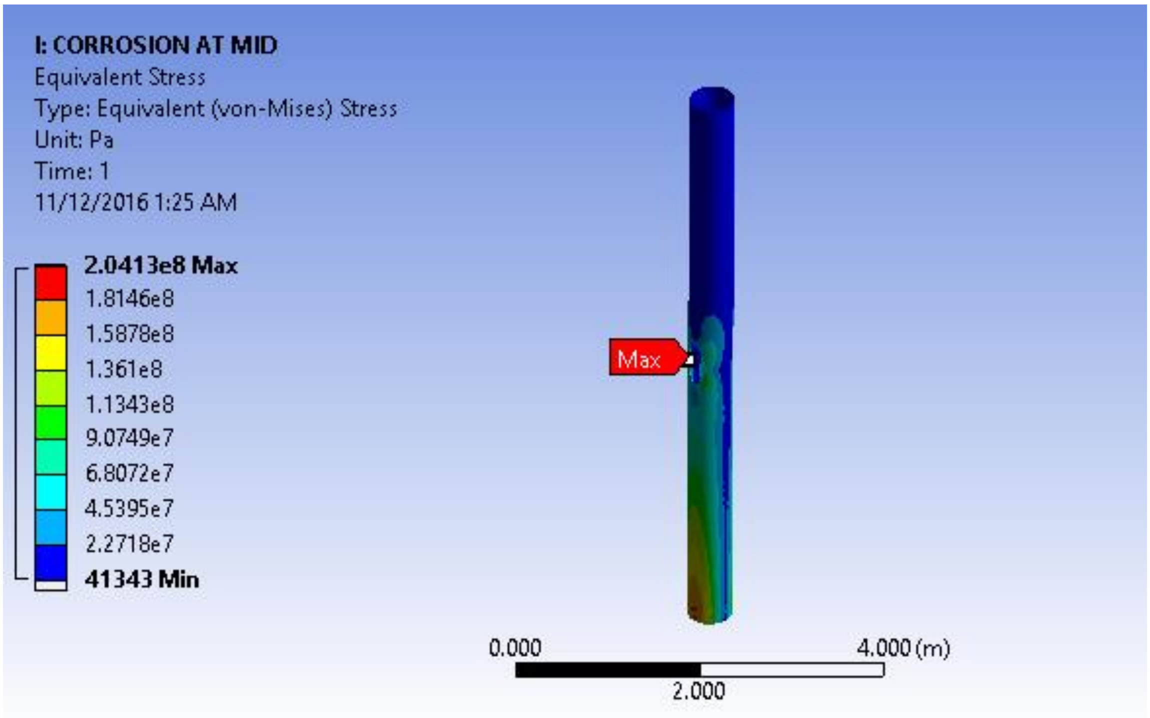


Figure 11. Von-Mises Stress result at 0 degrees

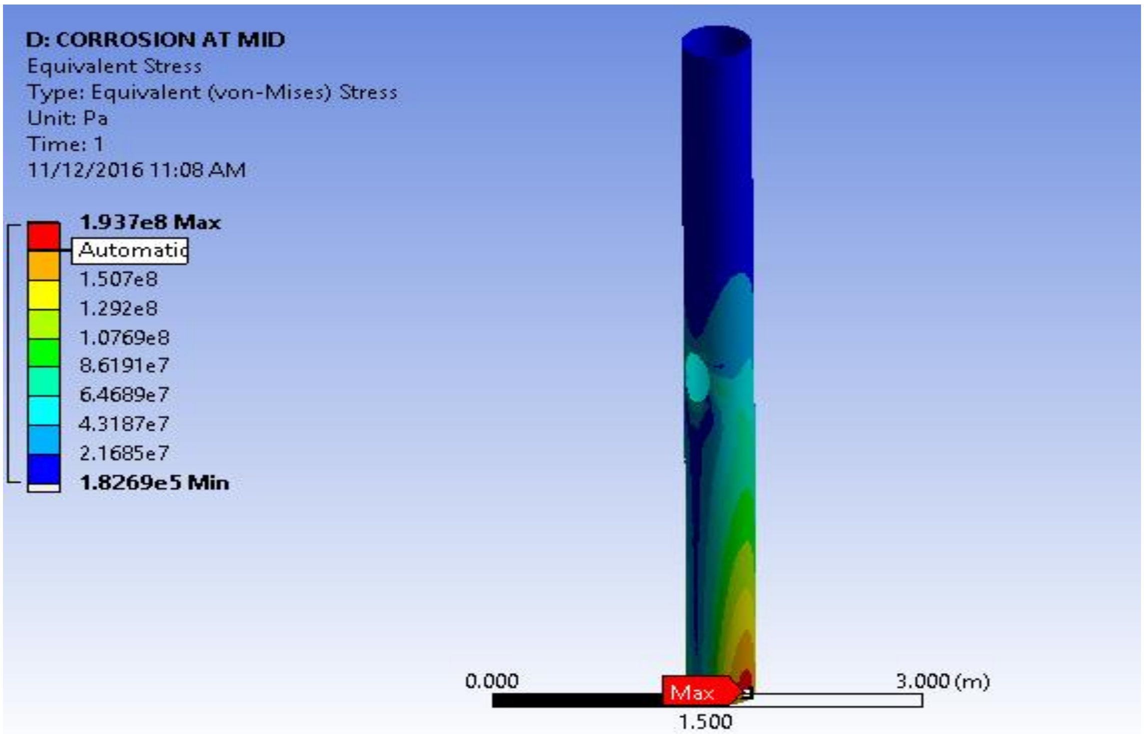


Figure 12.Von-Mises Stress result at 90 degrees

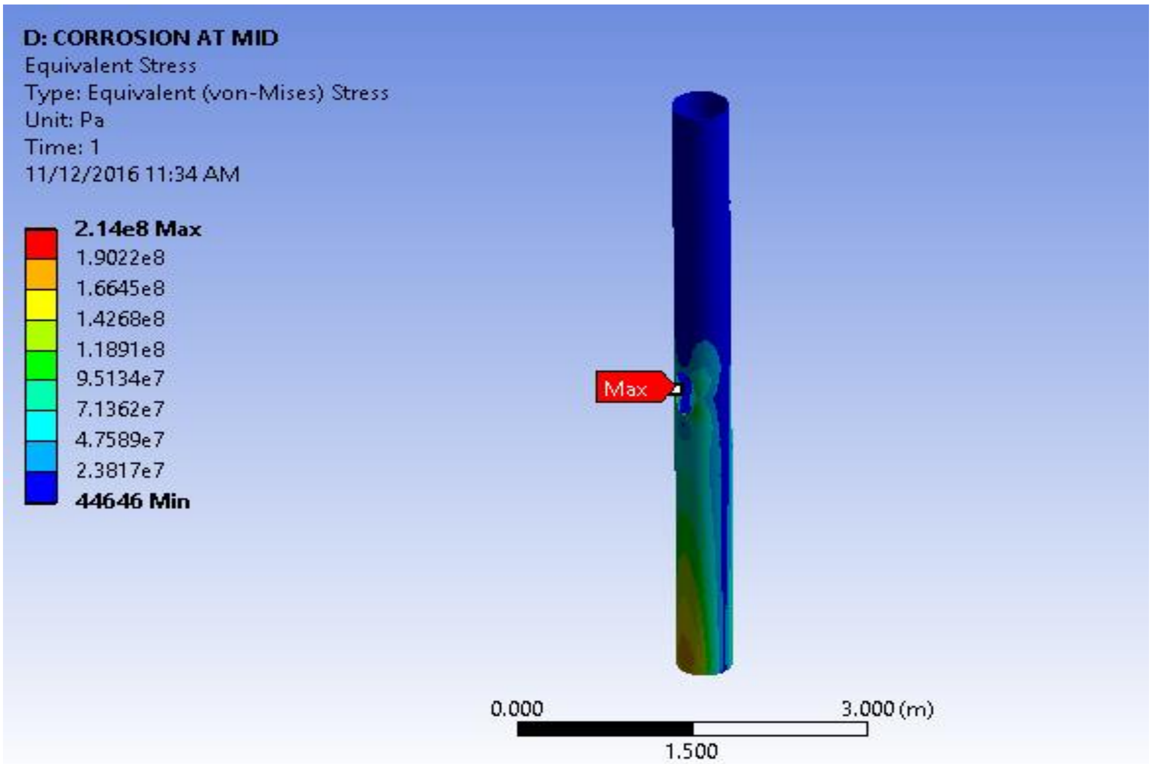


Figure 13. Von-Mises Stress result at 180 degrees

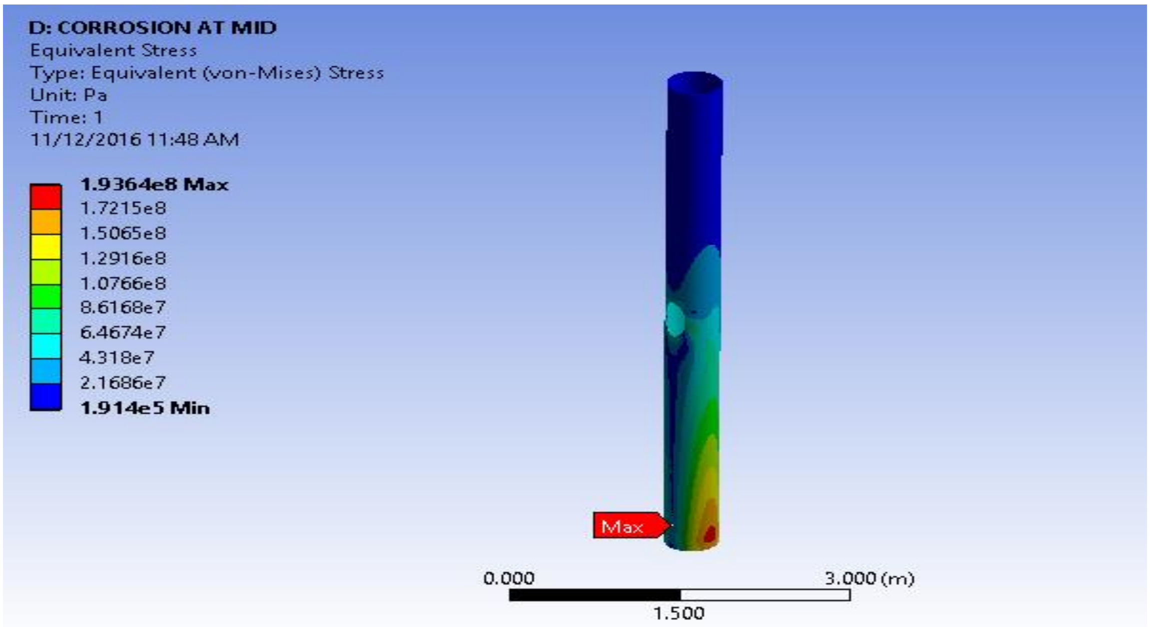


Figure 14.Von-Mises Stress result at 270 degrees

In summary, based on results obtained in Figure 12, 13, 14 and 15 above, the directional environment load application does not cause the structure similar stress Impact.

4.1.2 Total Deformation

Total deformation is the overall deformation of the structure in the X, Y and Z directions. It represents the global displacement as result of the applied loading.
Hence;

Total deformation = SQRT(X2 +Y^2 + Z^2)

Comparing deformation result and direction; in total deformation, high displacement is noted at the top of the jacket due to the minimal global stress at that point meanwhile for directional, high displacement is marked at the point of corrosion.

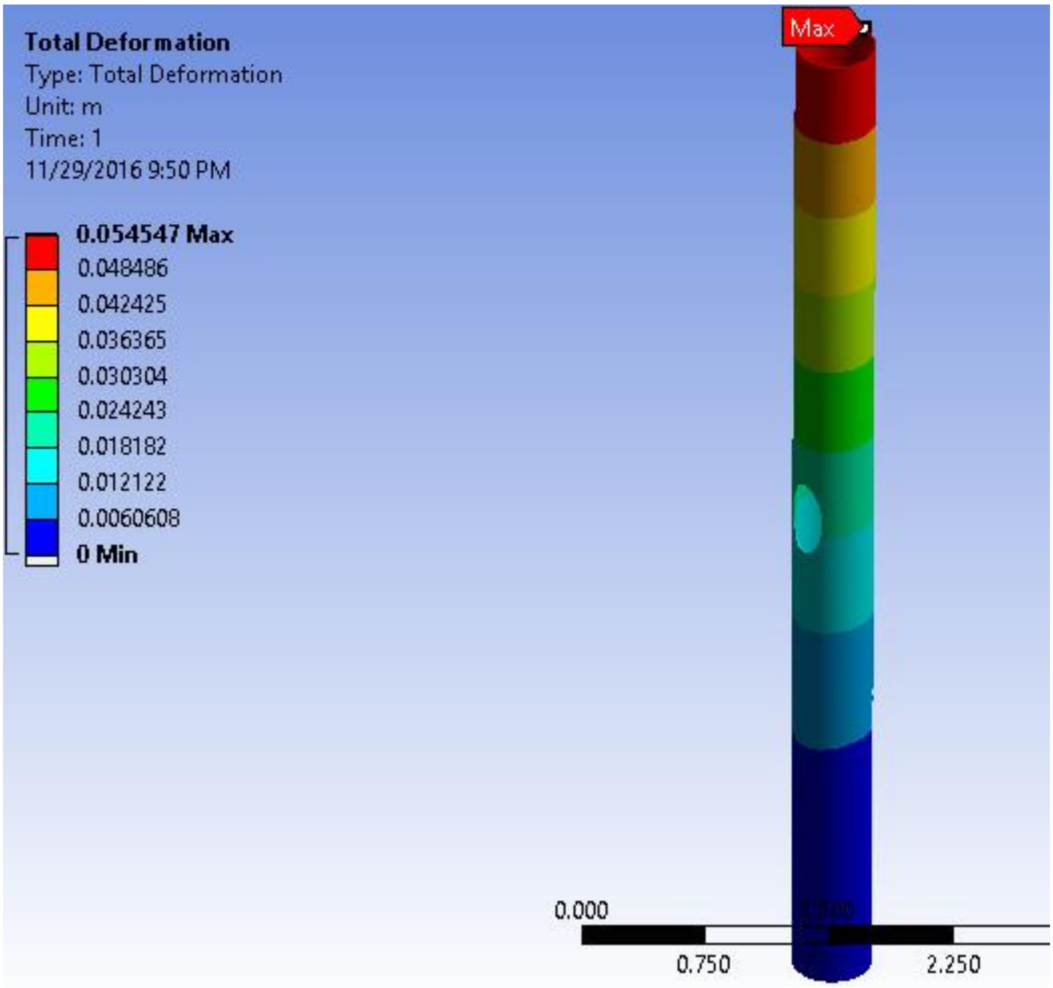


Figure 15. Total Deformation Result at Mid of section

4.1.3 Normal Stress

Normal stress is a stress value at single direction. The analysis helps to evaluate the impact caused by directional static loading on the structure. Results found by corrosion at the mid of the section are in Table 10 below:

Force (KN)	**Normal stress (MPa)**
100	92
110	102
120	111
130	120

Table 10. Normal stress value obtained on a mid corroded surface

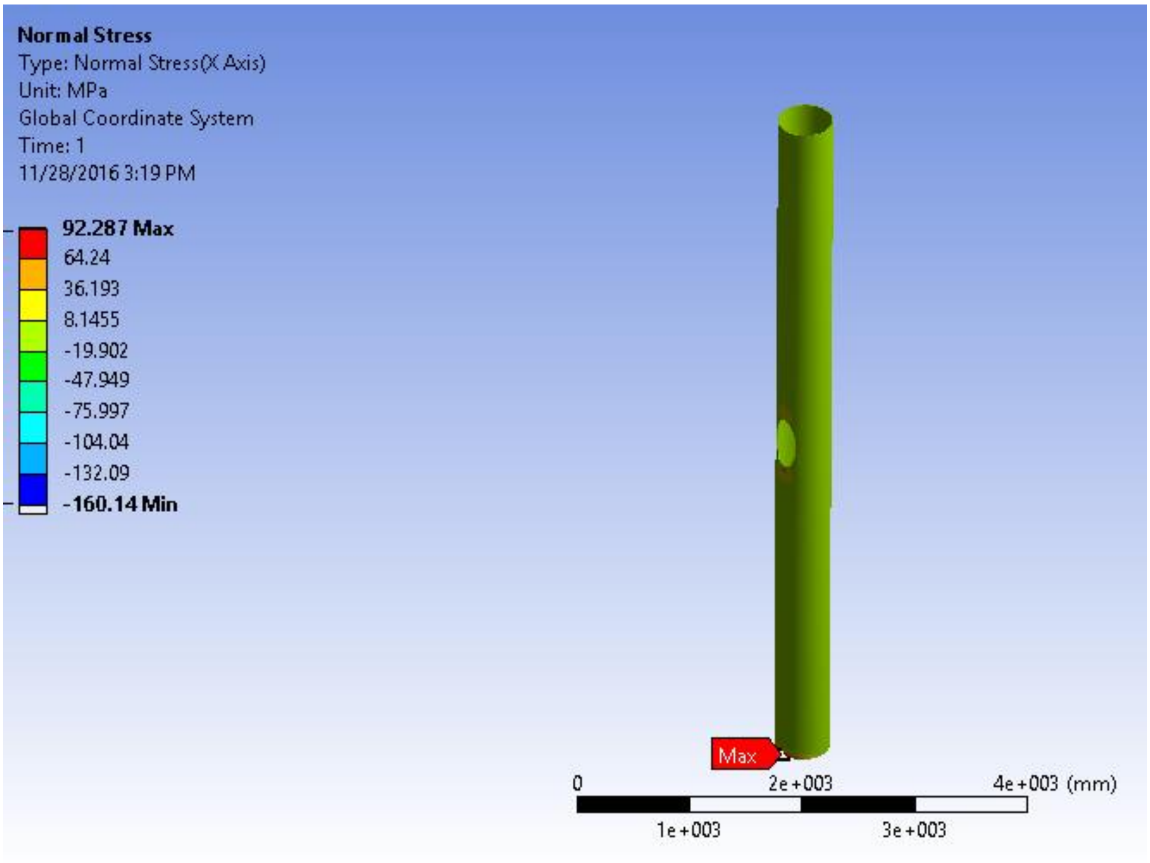


Figure 16. Normal stress at 100KN, mid corroded section

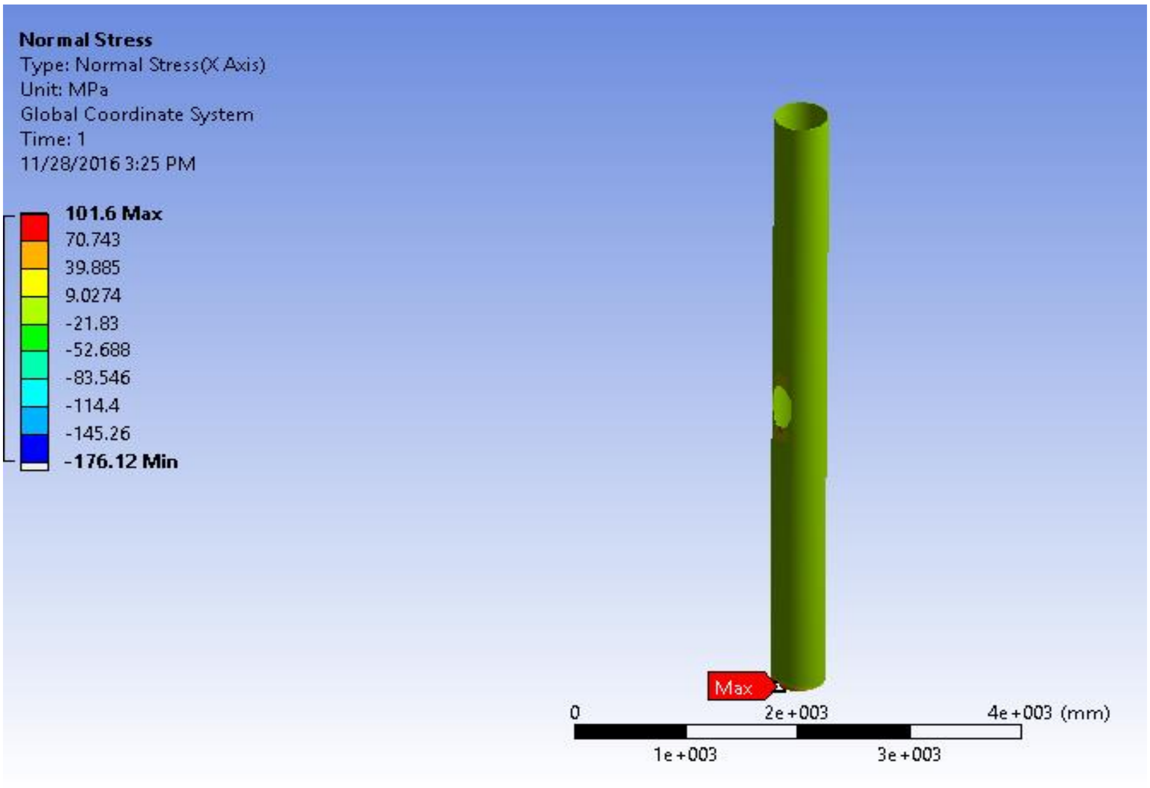


Figure 17. Normal stress at 110KN, mid corroded section

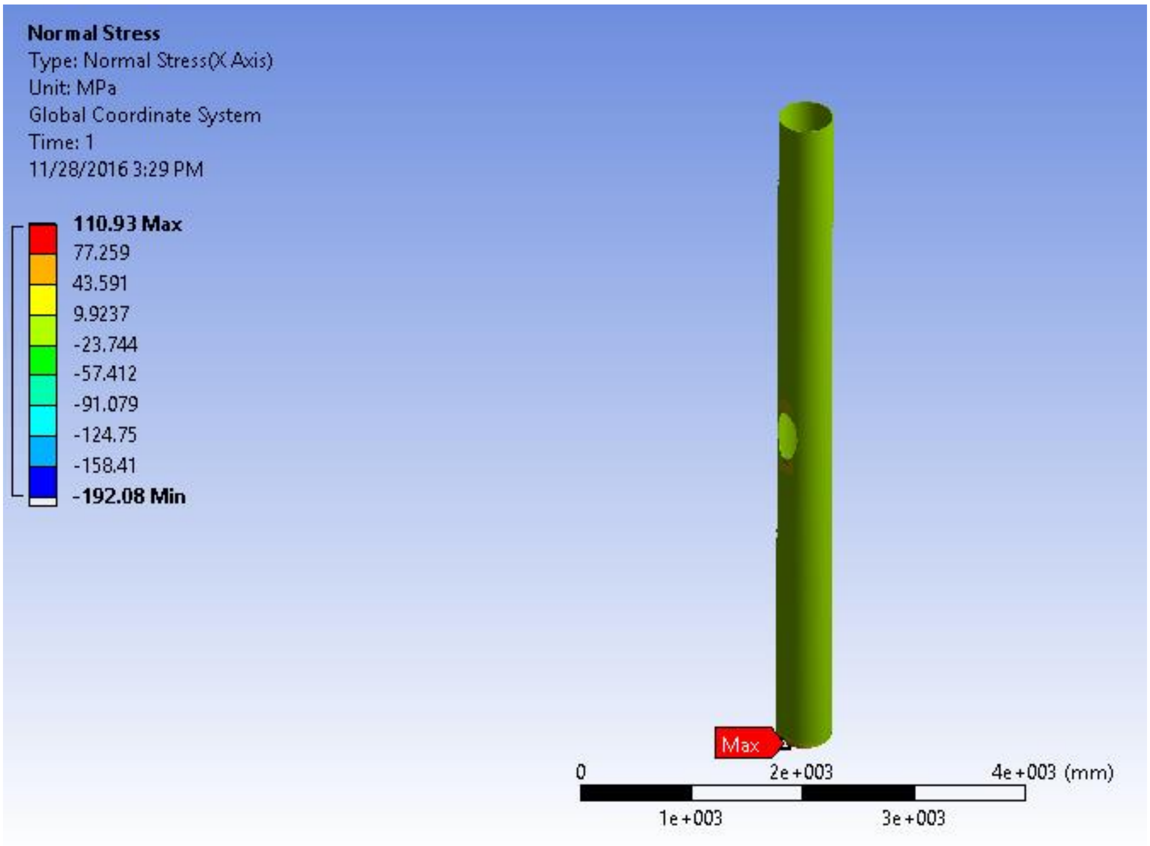


Figure 18. Normal stress at 120KN, mid corroded section

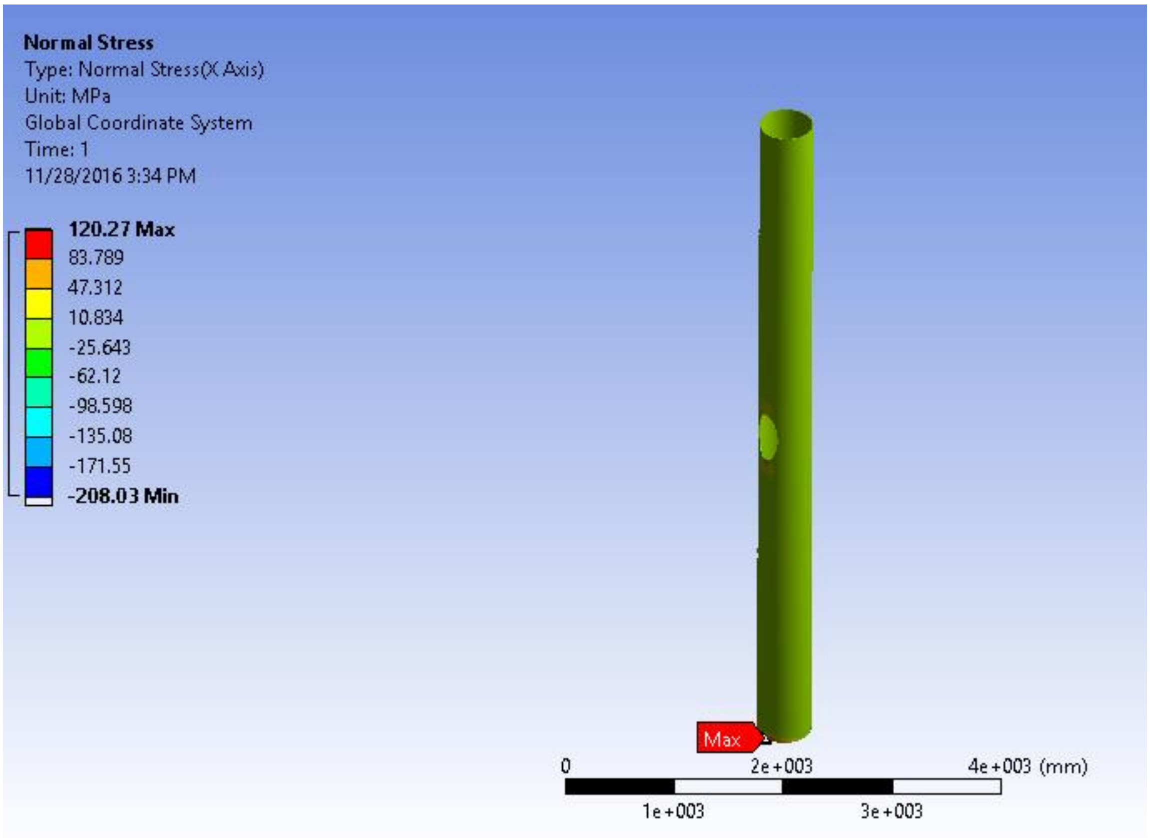


Figure 19. Normal stress at 130KN, mid corroded section

Equally, the directional deformation analysis helps to evaluate the impact caused by directional static loading on the structure. Results found by corrosion at the mid of the section are in Table 11 below:

4.1.4 Directional Deformation

Force (KN)	Directional Deformation (m)
100	0.000444
110	0.000487
120	0.000530
130	0.000573

Table 11. Directional Loading result at mid of the section

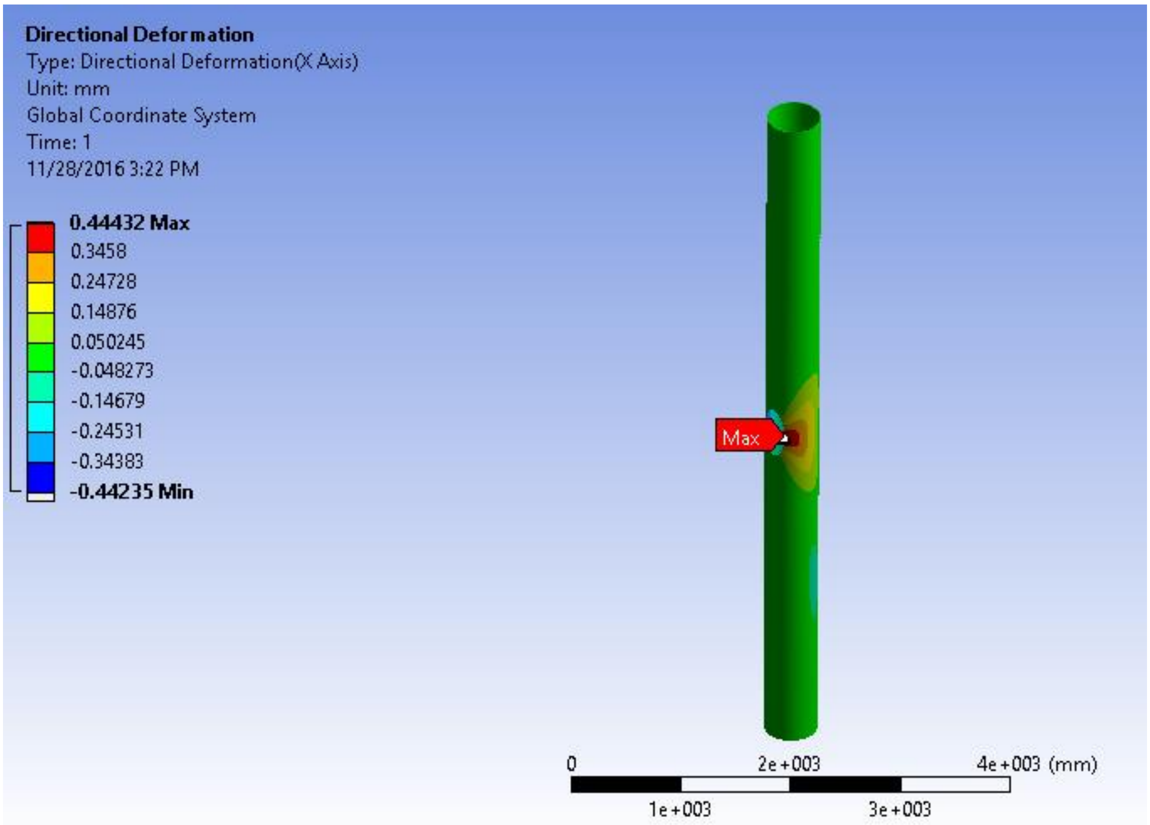


Figure 20. Directional deformation at 100KN, mid corroded section

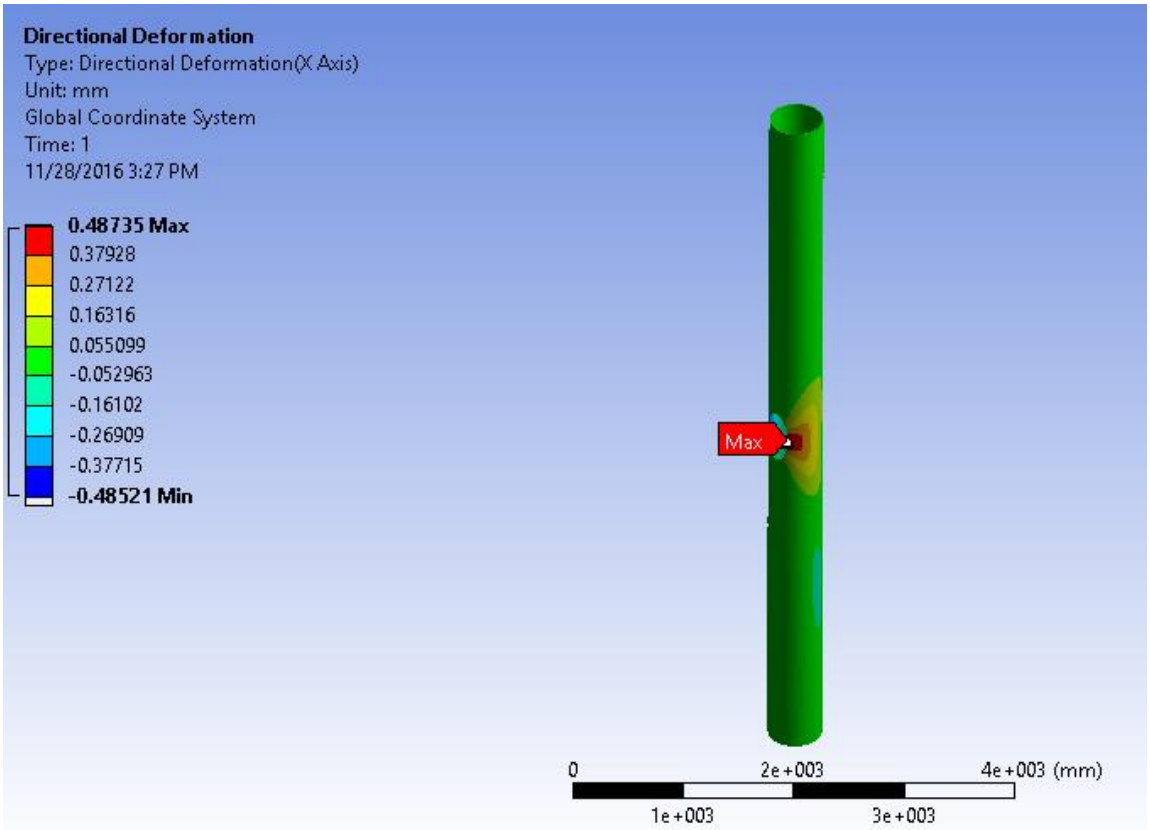


Figure 21. Directional deformation at 110KN, mid corroded section

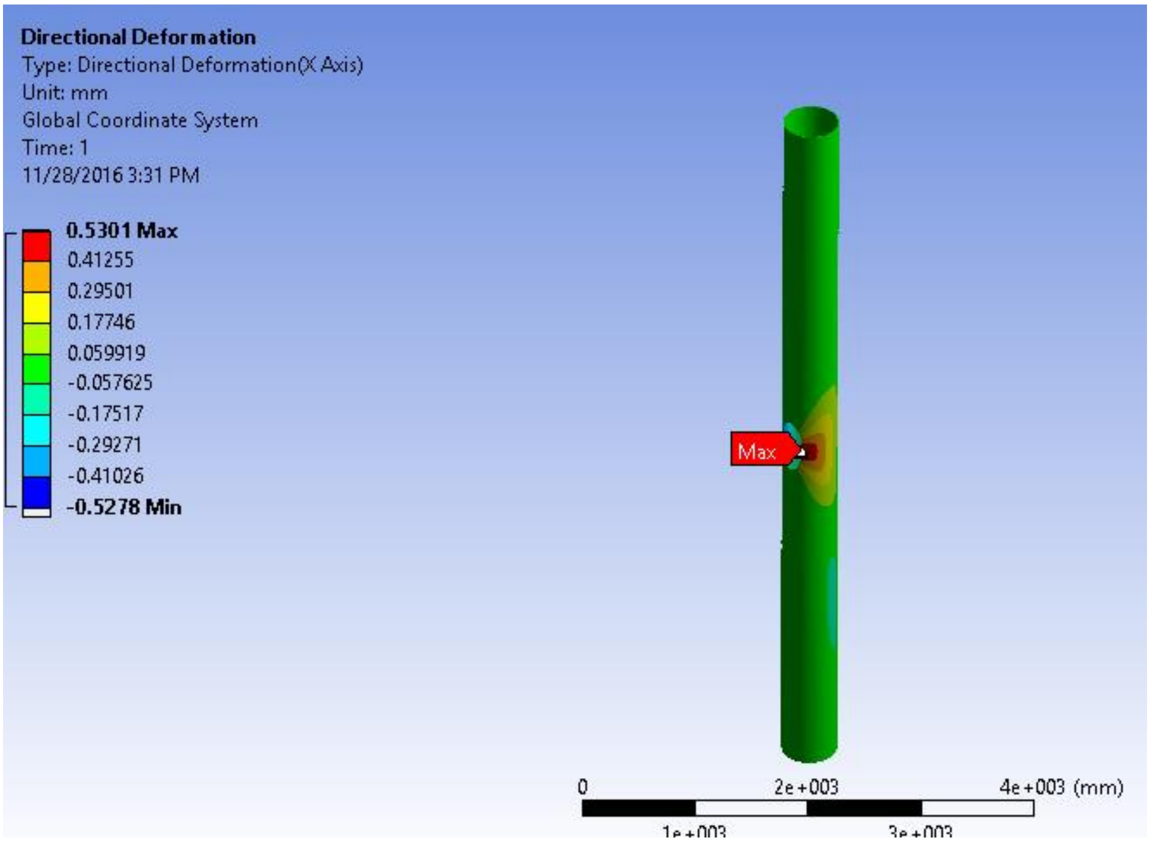


Figure 22. Directional deformation at 120KN, mid corroded section

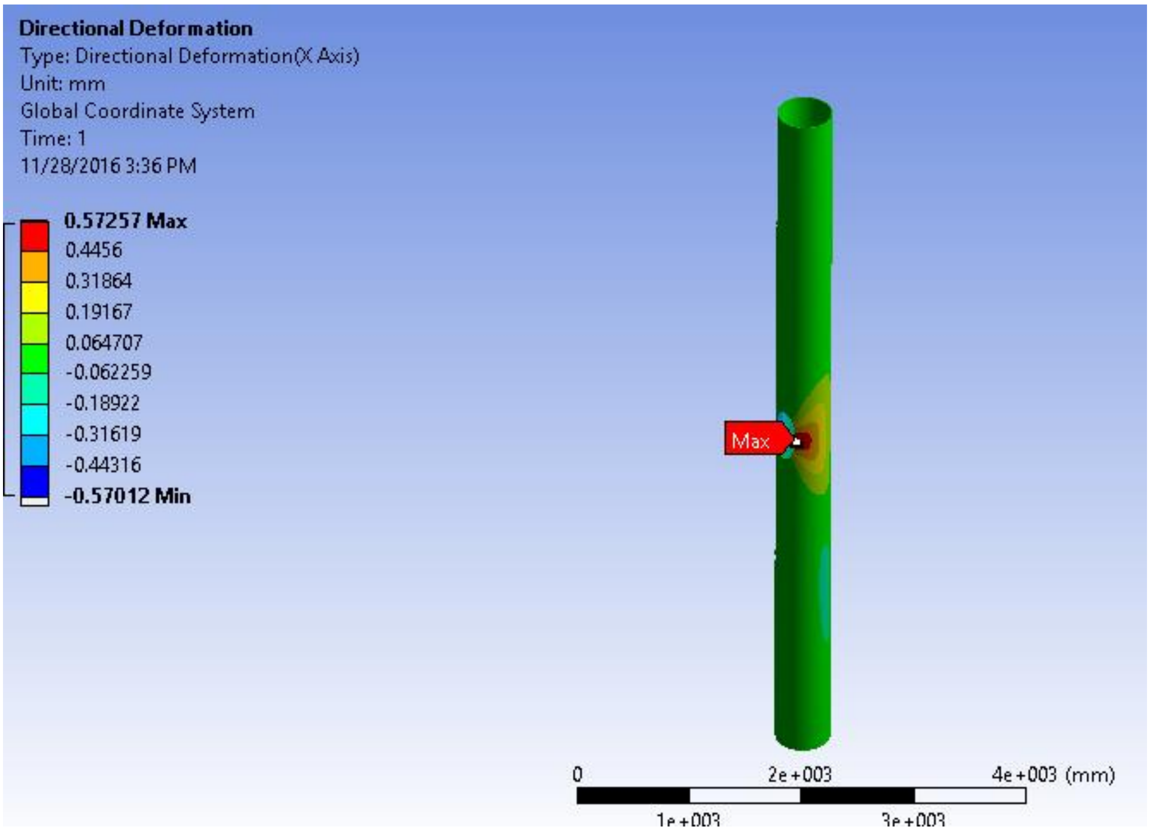


Figure 23. Directional deformation at 130KN, mid corroded section

In addition, Stress on the structure on the structure tends to be extremely higher when environmental loads acts at two different directions (-ve y & x-axis). This result therefore justifies the results obtained in a number of researches conducted on the impact of corrosion. However, not many researches have provided a realistic prove by use of the FEM analysis ANSYS.

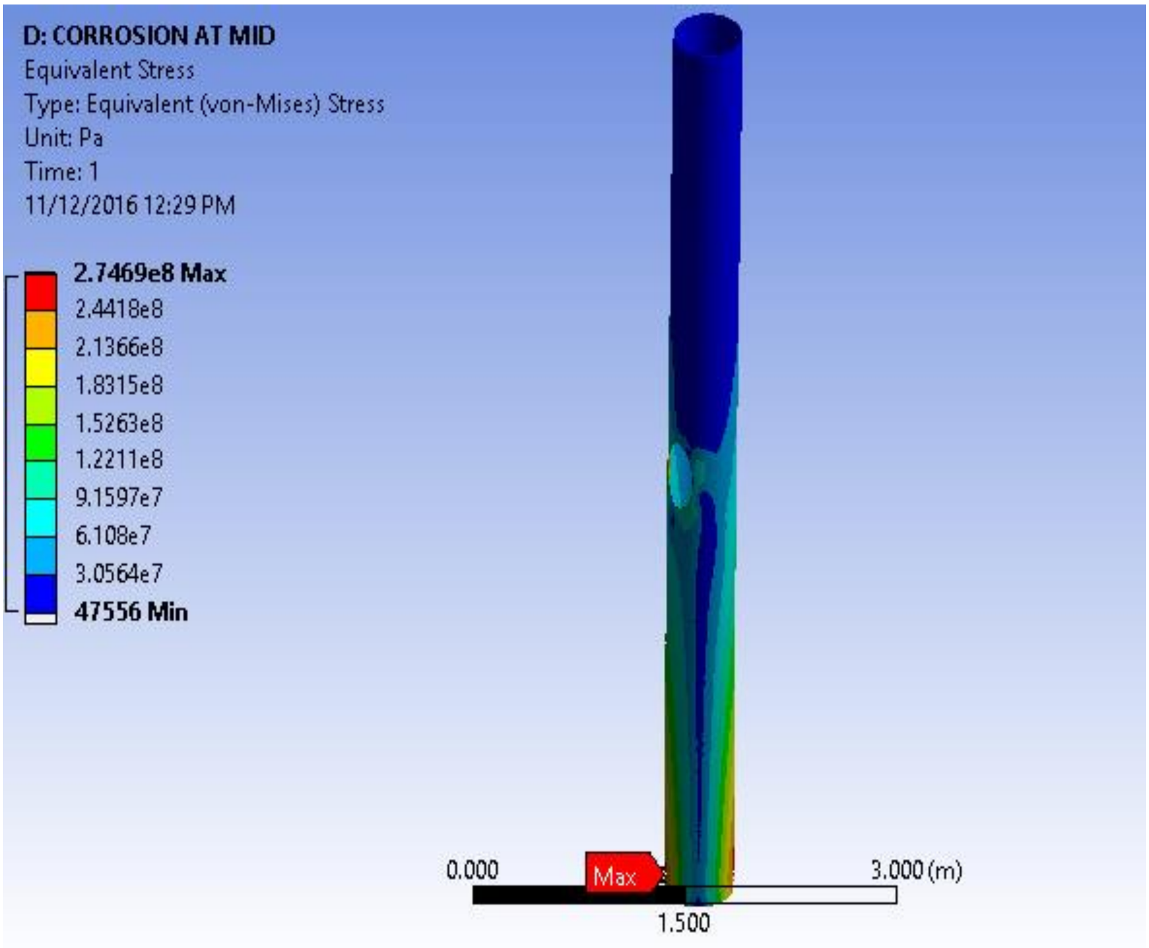


Figure 24. Environmental Load applied at 0 and 270 degree

4.2 *Impact of Corrosion size*

Corrosion sizes are varied based on the original shape at locations top, mid and bottom (next to fixed support) of the member. The results shows that the larger the corrosion size, the higher the Von-Mises stress and total deformation respectively. Much impact of the corrosion occurs at the area closer to the fixed joint, the mid and top part respectively. On applying 100KN in the negative Y of the member to the corroded (top, mid and bottom), the following results were obtained as in Figure 9, 10, 11 and 12 below.

a) Corrosion Size (Area= 0.0982 m^2)

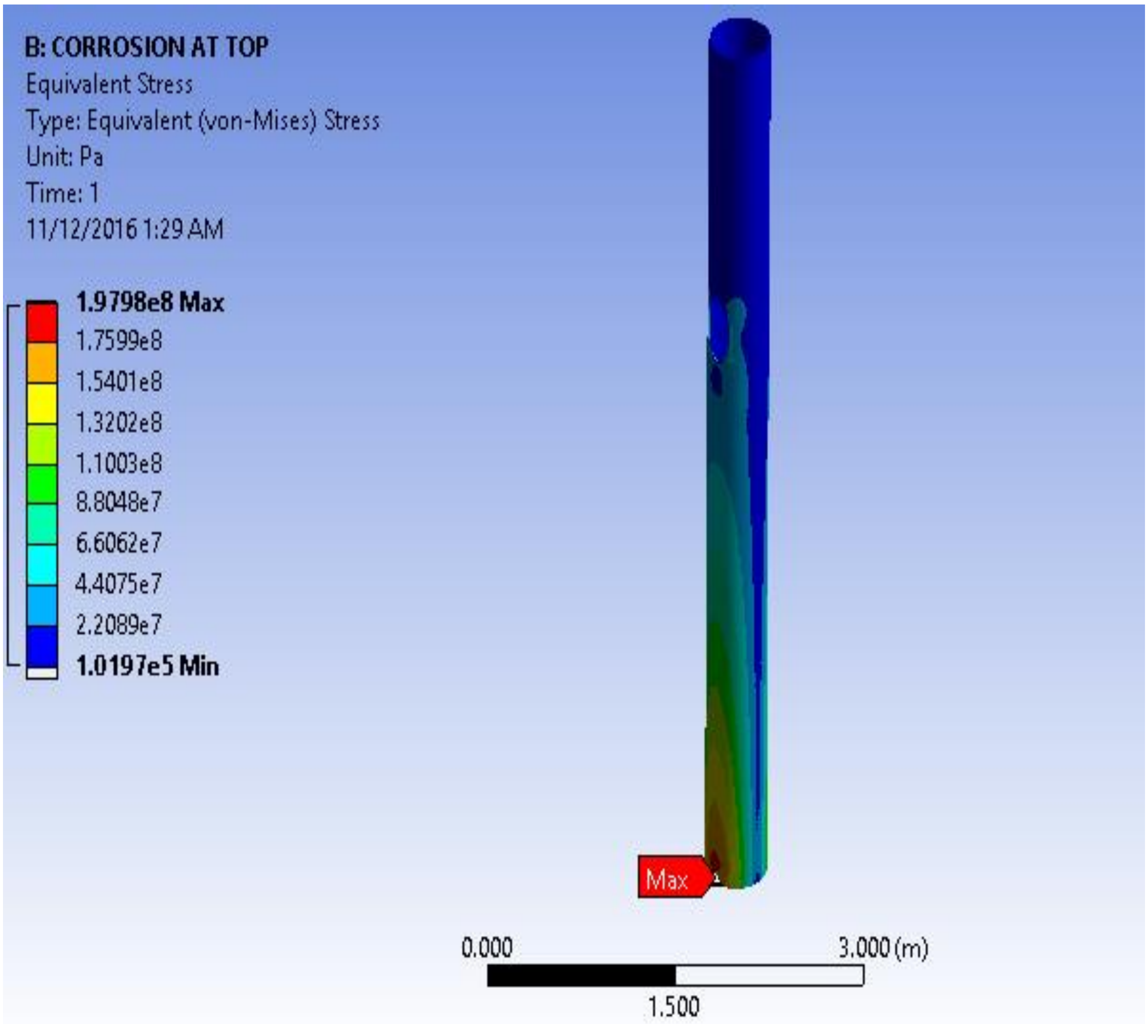


Figure 25. Corrosion at the TOP

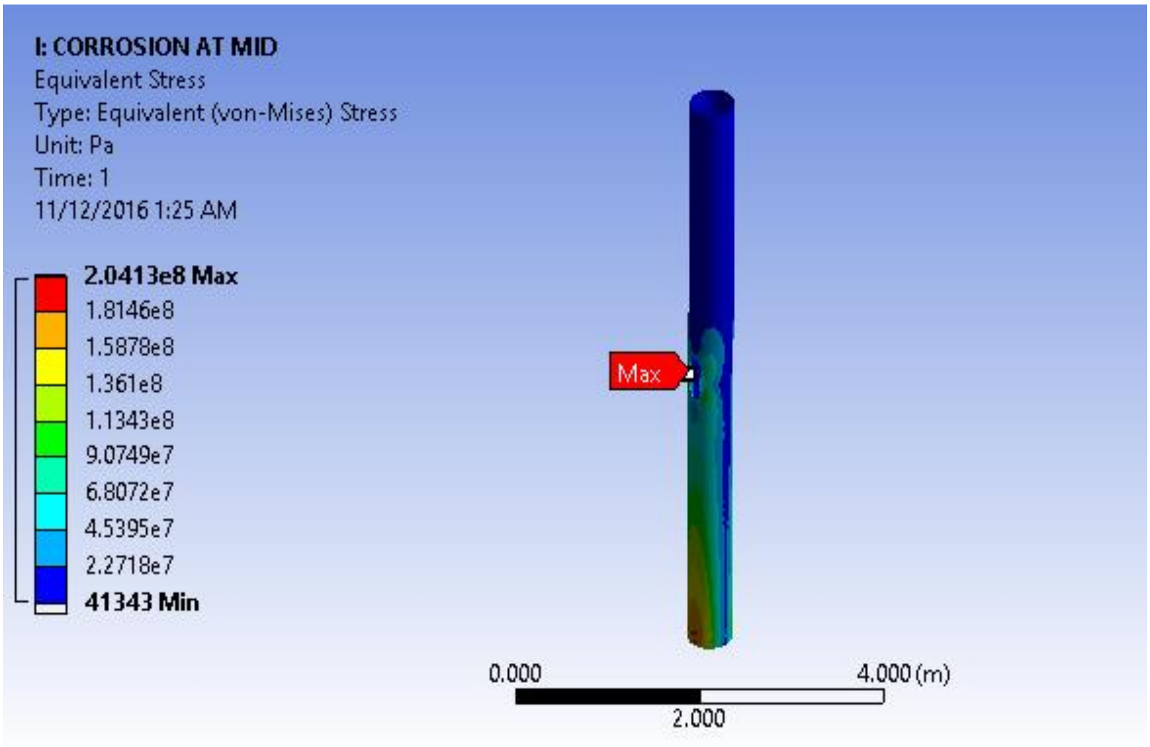


Figure 26. Corrosion at the mid

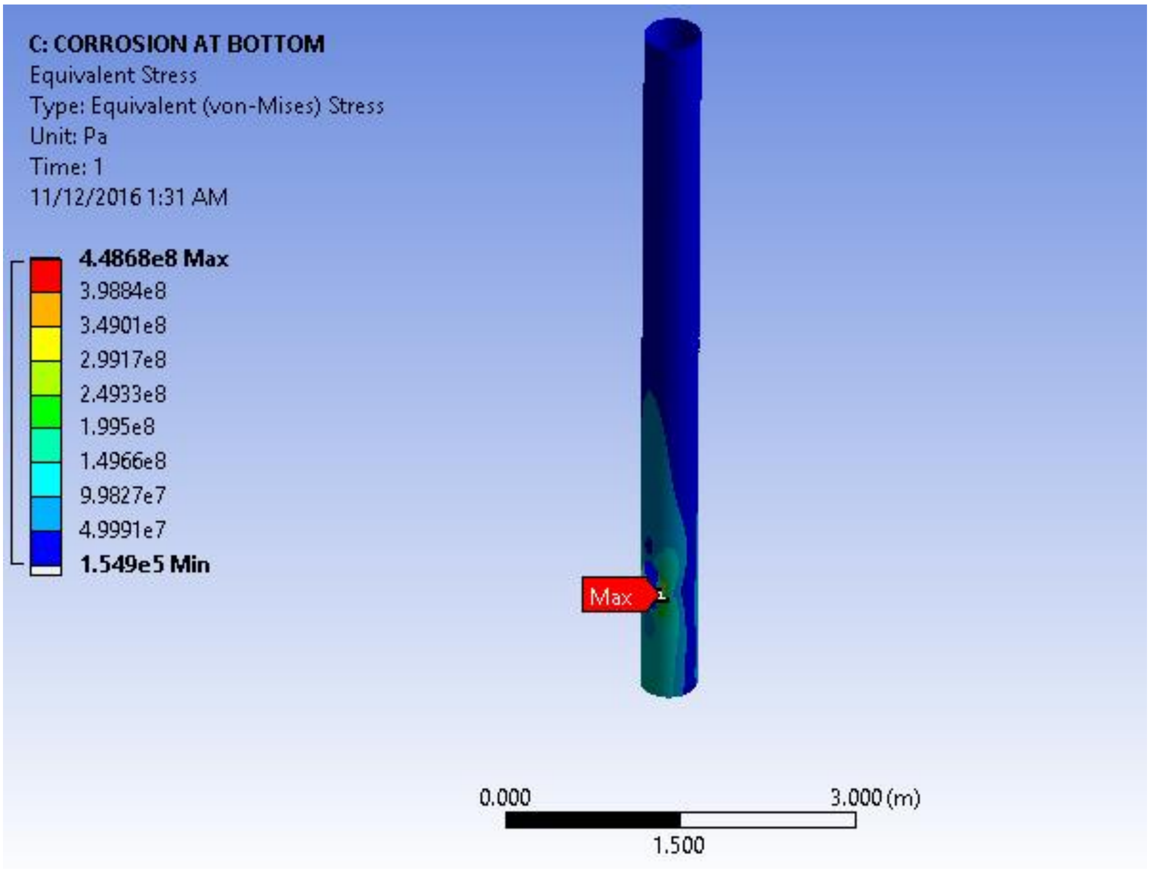


Figure 27. Corrosion at the bottom (next to joint)

Corrosion Size (Area= 0.0491m^2)

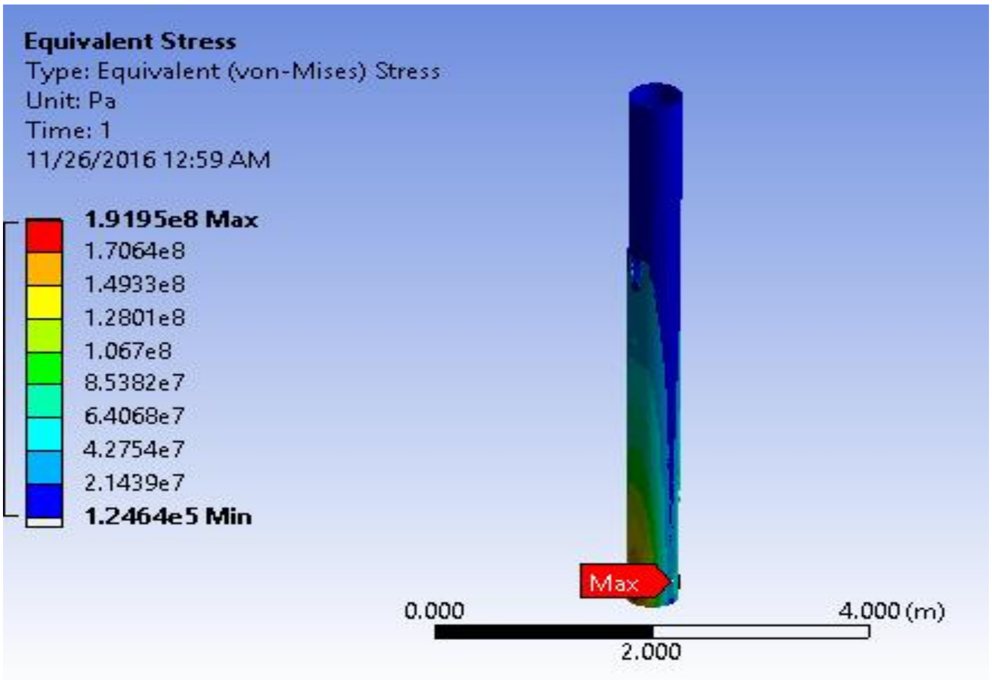


Figure 28.Corrosion at the TOP

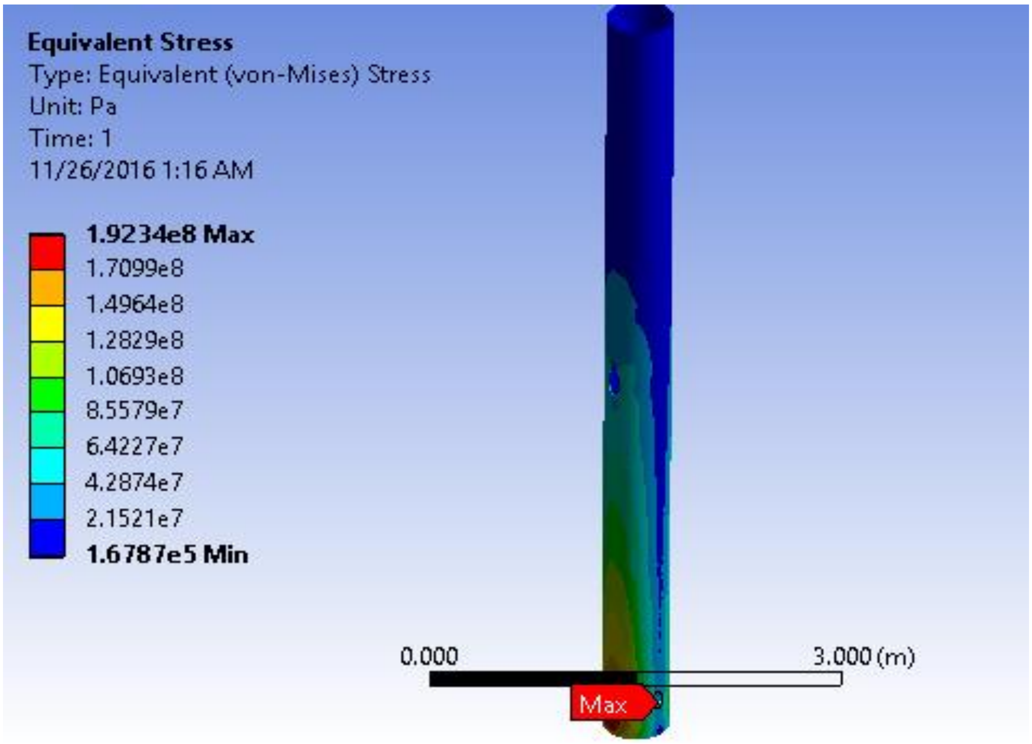


Figure 29.Corrosion at the mid

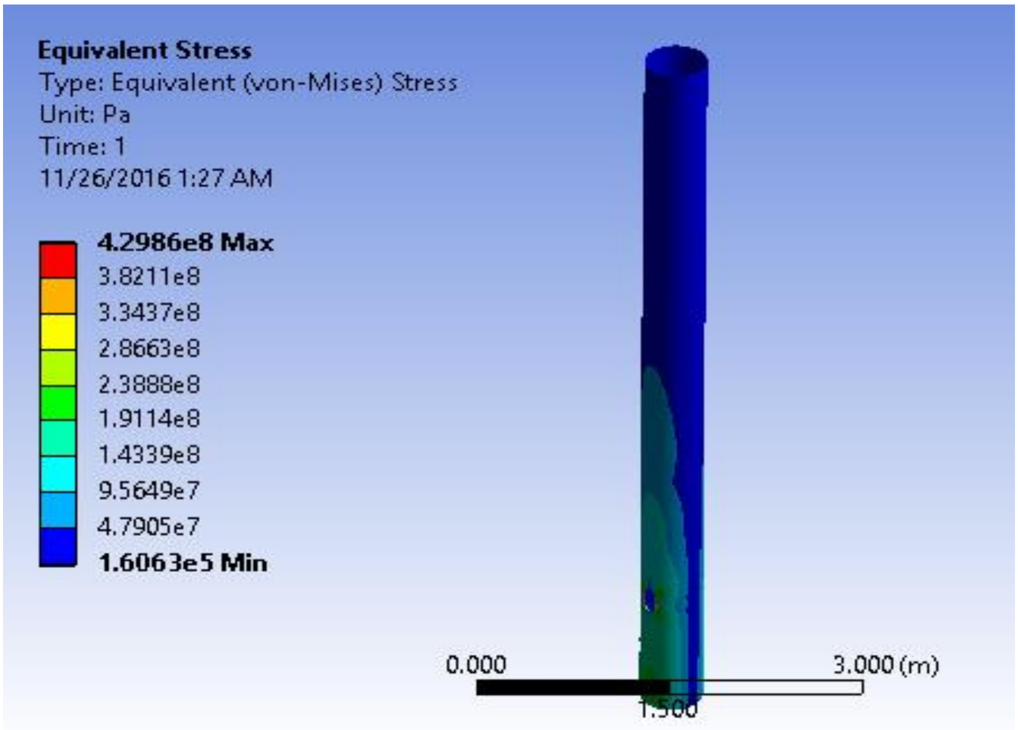
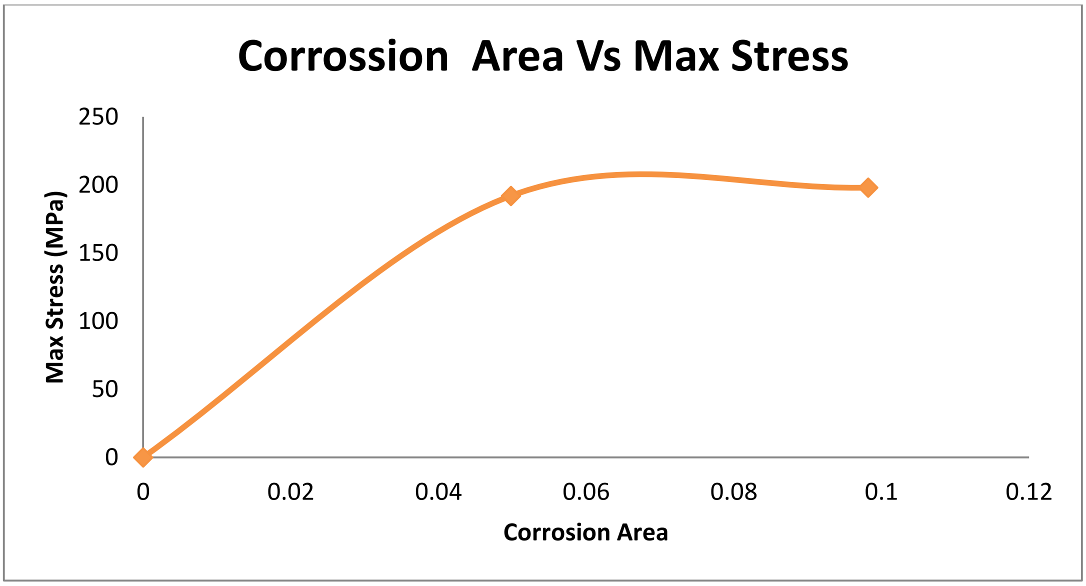


Figure 30.Corrosion at the bottom

Corrosion Area (m2)	Max Stress (MPa)
0.04982 (50%)	192
0.0982 (100%)	198

Table 12. Corrosion and equivament max stress



Graph 4. Corrosion Area Vs Max Stress

From the results obtained in Graph (2), stress value on the structure increases gradually with increase in the corrosion sizing.

4.3 *Corrosion Location*

The impact of corrosion location is discussed. Corrosion is varied at the mid of the 6.75m leg, 1.6875m above and below reference to the mid. Results shows that corrosion exerts extremely high impact at the location near to the joint support, mid and low to the top free end of the cantilever.

Steps	**Force (KN)**	**Max. Von-Mises Stress (MPa)**	**Max Total Deformation (m)**
1	100	204	0.04644
2	110	224	0.051084
3	120	244	0.055728
4	130	264	0.060371

Table 13. Corrosion at the mid of the Jacket leg

Steps	**Force (KN)**	**Max. Von-Mises Stress (MPa)**	**Max Total Deformation (m)**
1	100	204	0.04644
2	110	224	0.051084
3	120	244	0.055728
4	130	264	0.060371

Table 14. Corrosion near to the fixed joint of the Jacket Leg

Steps	**Force (KN)**	**Max. Von-Mises Stress (MPa)**	**Max Total Deformation (m)**
1	100	198	0.045138
2	110	218	0.049653
3	120	238	0.054168
4	130	258	0.058684

Table 15. Corrosion at the top of the Jacket

Results show that on increasing load at every step by 10KN, the leg structure is subject to 8 % Von-Mises stress increase and 9% total deformation

In addition, impact of location on corrosion could also be evaluated on four angle directions. In the part, static load was applied in the four different angles 0, 90, 180 & 270 degrees as shown in the Table 8 below. Results indicate that impact of corrosion on the four different angles are not the much similar. Load application on affected face 0, & 180 degrees of the leg structure causes high stress impact, hence loss of the structural capacity as compared to 90 & 270 degrees.

Load (KN)	Directions (degree)	Max. Von-Mises Stress (MPa)
100	0	204
100	90	194
100	180	214
100	270	194

Table 16. Angle variation on an applied static load on a corroded surface

Load (KN)	Directions (degree)	Max. Von-Mises Stress (MPa)
100	0	189
100	90	200
100	180	189
100	270	200

Table 17. Angle variation on an applied static load on uncorroded surface

Therefore, corrosion impact on the location of the corroded surface due to the applied static loading is more crucial to consider. Otherwise, considering corrosion at a constant loading direction can be regarded less sensitive as the effect entirely depends on the corrosion sizing. It is there significant to know the directions of the environmental loadings the structure is subjected.

CHAPTER 5

5.0 CONCLUDING REMARKS

This study attempted to evaluate the impact of corrosion size and location on the jacket leg of a platform. The result shows that both Size and location of corrosion compromises the structural integrity of the leg structure. The Structure is subjected to approximately 10% stress reduction by variation of its sizing by 100% and 50% when a 10KN static lateral load is applied on the structure. Meanwhile, for location variation, it loses about 8%. Results obtained for size and location are both significant for the structure's integrity. This result confirms to the latest findings (Sari, et.al, 2016) that location is less sensitive to the reliability of the structure. However, the value difference (2%) obtained in this research is minimal to conclude that location is less sensitive.

The following recommendations are advised:

I. Additional parameter such as corrosion depth has to be evaluated to determine its influence on the structural integrity.

II. Analysis has to be conducted on the overall jacket platform structure to validate the results found.

III. More research in this area of study is advised using ANSYS FEM software.

REFERENCE

ANSYS Analysis User's Manual V.6.8, 2011

Ali Sari, P. D., P.E., Genesis Houston; Ekkirala Ramana, Technip Malaysia; Hieu Nguyen, PH.D., P.E., Genesis Houston; Amir Arablouei, PH.D. and Umid Azimov, Genesis Houston. (2016). Structural Corrosion Modelling for Strength Assesment of Fixed Offshore Platforms for Life Extension Study. *Offshore Technology Conference*(OTC-26521-MS).

Anto, P. F., (1999). Pitting Corrosion On Weld Joints Offshore Structure Jackets. *Corrosion 99*(324).

Kurian, V.J., Voon, M. C., Wahab, M.M.A., and Liew, M.S., (2014). System Reliability Assessment of Existing Jacket Platforms in Malaysian Water. *Applied Sciences, Engineering and Technology, 8*(23), 2305-2314.

Nakai, T., Matsushita, H., Yamamoto, N., (2005). Effect of Pitting corrsion on local strength of hold frames of bulk carriers (2nd report)-laterral-distortional buckling and local face buckling. *Marine structures, 17*(2004), 612-641.

Nazari, M., Khedmati, M. R., and Khalaj, A.F. A numerical investigation into ultimate strength and buckling behavior of locally corroded steel tubular members. *Department of Marine Technology, Amirkabir University of Technology, Iran.*

Paik, J. K., Lee, J. M., & Ko, M. J. (2004). Ultimate shear strength of plate elements with pit corrosion wastage. *Thin-Walled Structures, 42*(8), 1161-1176.

PETRONAS Technical Standard. (2012). 34.19.10.30 Design of Fixed Offshore Structures. Malaysia: Petroliam Nasional Berhad.

Rahgozar, R. (2008). Remaining capacity assessment of corrosion damaged beams using minimum curves *Journal of Constructional Steel Research, 65*(2009), 299-307.

Tan, C., Lu, Y., Zhang, X., (2016). Life extension and repair decision-making of ageing offshore platforms based on DHGF method. *Ocean Engineering, 117*(2016), 238–245.

Sadovsky, Z., Drdacky, M., (2001). Buckling of plate strip subjected to localised corrosion—a stochastic model. *Thin-Walled Structures, 39*, 247–259.

Salau,M.A., Esezebor,D. E., E., Omotoso, M.F., (2011). Reliability Assessment Of Offshore Jacket Structures In Niger Delta. Petroleum & Coal, 53(4), 291-301.

Xie, J. (2012). Finite Element Analysis for Structural Performance of Offshore Platform

Zve, E.V., Loukogeorgaki, E., Angelides, D.C.,(2015). Effect of Zoning Corrosion on the Life-Time Structural Reliability of a Jacket Offshore Structure. International Ocean and Polar Engineering Conference.