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SIMULATION OF RING CONNECTION MODIFICATION ON FLARE STACK STRUCTURE

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ABSTRACT

The flare stack serves to protect process equipment facilities against unexpected overpressure. This study aims to follow up on previous research that recommends improvements to the flare stack structure based on corrosion findings that occur in the area of the riser stack around the ring connection for the guy wire. By replacing rusty material, it is also necessary to consider modifications to prevent the risk of re-corrosion. Based on current design observations in the connection ring area for guy wire, side cutting is required which can result in water being trapped. This research aims to find out whether by modifying the connection ring for guy wire, this flare structure still has structural reliability when receiving critical outer loads or not. Based on the results of the study, it shows that modifying the geometry of the connection ring guy wire still provides reliable structural performance when receiving critical outer loads. The maximum stress that occurs in the area around the pad eye is 71.2 Mpa with a maximum stress ratio of 0.434 it shows that the value is still quite far from the maximum allowable voltage ratio of 1.0. So it can be concluded by modifying the connection ring for guy wire to prevent the risk of corrosion can be done without causing a decrease in the performance of the structure in withstanding critical outer loads.

Keywords: *flare stack, connection ring for guy wire, max stress*

1. INTRODUCTION

Flare installation is a safety system for over-pressured gas that came from the production process, which is to burn the gas that came out from the production process (Bassey 2008). In the actual production place, we found this flare facility in the shape of a vertical chimney known as, Flare Stack. A Flare stack is a vertical-shaped facility used in oil well, gas wells, oil rigs, factories, chemical plants, and natural gas plants. This apparatus is used to eliminate gas waste that can't be transported or used. This apparatus used a gas safety system, called a Pressure Relief Valve, that worked if needed to drop the pressure on the equipment (Ohio Epa

2014). The general shape of the flare stack is shown in Figure 1.

Figure 1. Flare Stack

When designing the location and height of the flare stack on a Processing Facility, consider minimizing the radiation exposure that is allowed by the employee or the equipment facilities. There are several types of Flare stack that we could find on the field, which are:

1. Self-supported flare stack
2. Guye wire supported flare stack
3. Derrick supported the flare stack

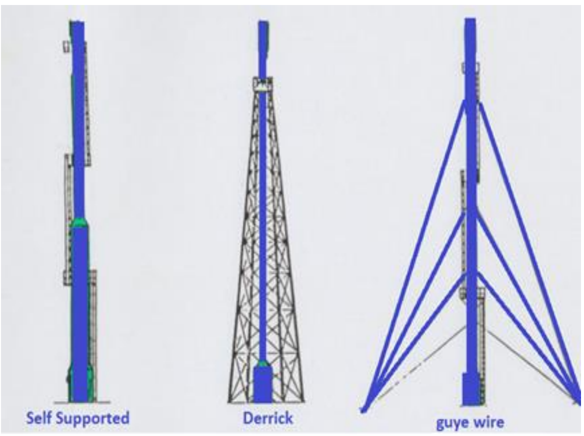


Figure 2. Type Flare Stack Structure

In the Natural Gas and Oil Industries, Flare Stack is usually tower-shaped from the oil process where all the gas already separated from unused oil will be sent to the facilities for burnt. In general, a flare stack is used to protect all equipment from overpressure.

2. BASIC THEORY

Computation Of Finite Element

Structure modeling in this research used a numeric method called the Finite Element Method. The main structure for this Flare Stack uses a Steel Pipe structure (Riser), in addition to the Steel Pipe Side, which also, had Connection Ring where installed Cable Element (Guye Wire). The structure element explained above will be said as Plate Element.

Computation Application used in this research using a commercial standard finite element basis called STAADPro. The plate elements that are used are Triangle Elements (3-Noded) or Square Elements (4-Noded). Based on the local coordinate location shown in Figure 3.

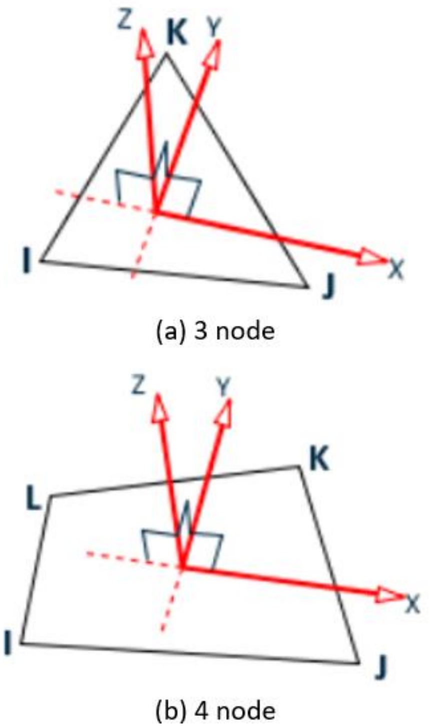


Figure 3. Plate Element

Normal Stress and Shear Stress Coordinate Axis are shown in Figure 4

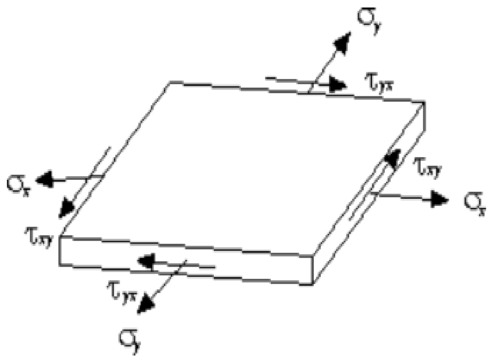


Figure 4. Normal Stress and Shear Stress

General Formula used for calculating the normal stress distribution with shear stress as shown in Equation-1

$$\begin{pmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{pmatrix} = \begin{bmatrix} 1 & x & y & 0 & 0 & 0 & 0 & x^2 & 2xy & 0 \\ 0 & 0 & 0 & 1 & x & y & 0 & y^2 & 0 & 2xy \\ 0 & -y & 0 & 0 & 0 & -x & 1 & -2xy & -y^2 & -x^2 \end{bmatrix} \begin{pmatrix} a_1 \\ a_2 \\ a_3 \\ \dots \\ a_{10} \end{pmatrix} \quad (1)$$

Where a is Stress Polynomial Constant

Wind Load

The critical load applied on the connection ring is taken from vendor data. From the vendor, a drawing can be found that max. The guye wire load is 16,410 lbs.

3. FLARE STACK DESIGN EXISTING

Sub-section

The total height of the *Flare stack* is 30.5 meters. This structure is supported by 3 (three) *guy wires installed on 22 meters from ground level. The riser material* is built from carbon steel pipe with a 36" diameter, sch. Std, material A-283 Gr.C

The general arrangement drawing of the *flare stack* can be shown in Fig. 5 and Fig .6.

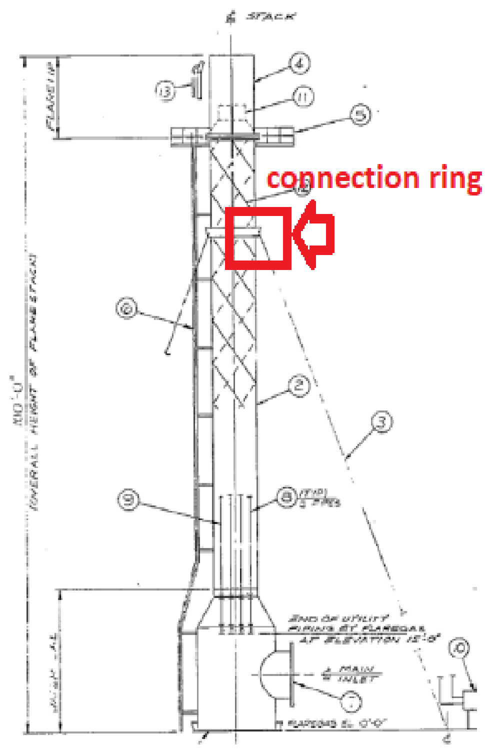


Figure 5. General Arrangement of Flare Stack

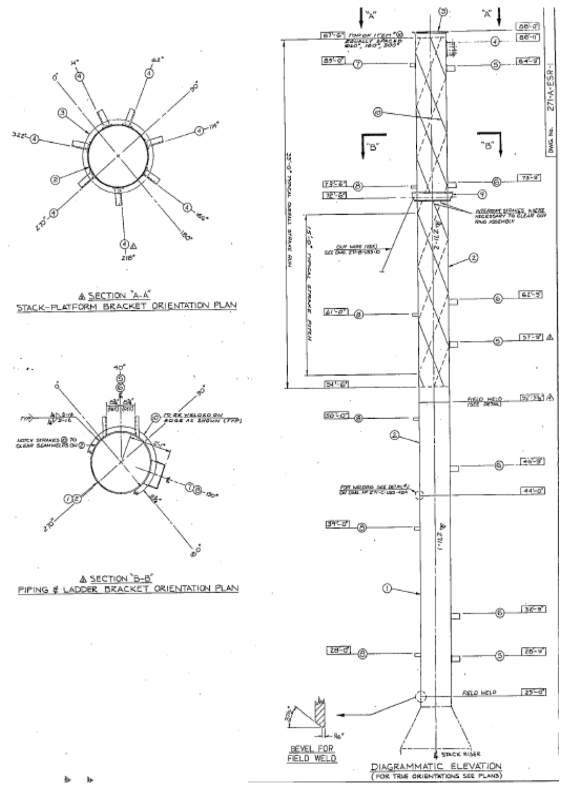


Figure 6. Stack Detail Drawing

4. FLARE STACK INSPECTION DATA

From the inspection, the result found that there are from Riser Stack that is already corroded and a hole in some areas on the elevation of 22 meters from the ground level on the connection ring guye wire areas shown in Figure 7 and Figure 8.

Figure 7. Hole Condition No. 1

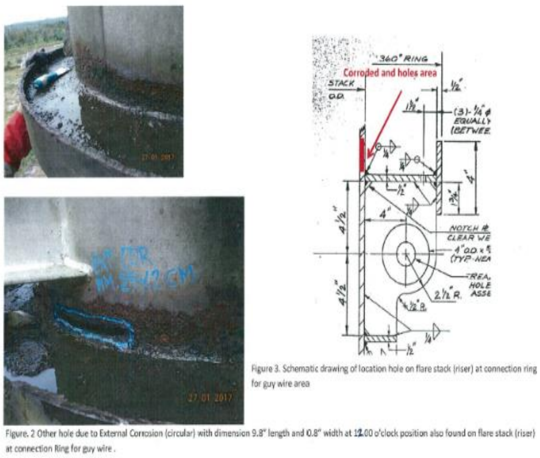


Figure 8. Hole Condition No. 2

Hole No. 1 is located in North West with a size of 2.4" x 1.2". For hole no. 2 located on the North with the size of 9.8" x 0.8" (Figure 9)

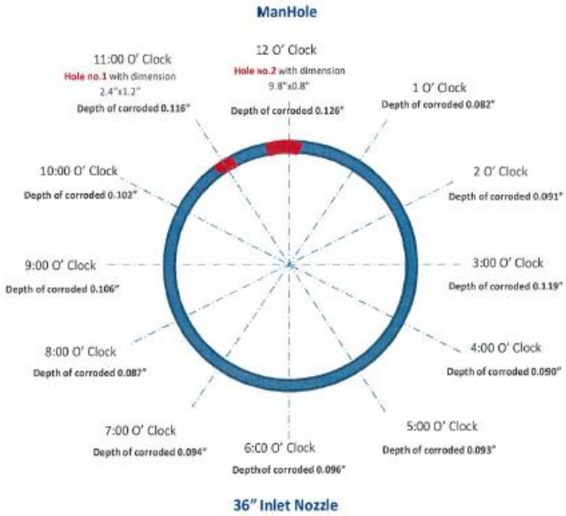


Figure 9. Hole Location at Stack

Thickness Reduction Distribution on Steel Material on the Riser Stack Wall on the Connecting Ring Area (Guye Wire) with a diameter of 36" and initial thickness of 0.25" as seen in Table 1.

Table 1. Corrosion Scale Data

Position (Clock)	Depth of corroded (inch)	Height (inch)
12:00	0,126	3,150
01:00	0,082	2,756
02:00	0,091	2,756
03:00	0,119	3,543
04:00	0,090	2,953
05:00	0,093	2,756
06:00	0,096	2,559
07:00	0,094	3,425
08:00	0,087	3,346
09:00	0,106	2,756
10:00	0,102	3,937
11:00	0,116	3,740

From the Inspection team information, the corrosion rate is about 0.176 mm/year.

5. PREVIOUS RESEARCH

The Research Result shows that with the plate thickness reduced in the area around Connection Ring Guye Wire will highly affect Stack Structure Capabilities on receiving outside load (Wind Load) (Satiawan, Rahayu 2022).

6. PROBLEM IDENTIFICATION

Based on the corrosion founding that happened on the Riser Stack Area around Connecting Ring Guye Wire will result in decreasing structure strength against the Outside Load. Taking into account that potential corrosion in the same area will not happen, we need to consider the Existing Structure Evaluation on the corroded location.

Based on actual design observation on the connecting ring for Guye Wire, there was a geometry shape that had a rainwater trap potential that in the long term will produce corrosion. To reduce the risk of water being trapped in the area by cutting the area need to be studied if it will reduce Riser Structure Strength so that will make the structure's capabilities decreased for withstanding the critical load or not

7. RESEARCH PURPOSES

This research purpose is to know if we modified the connection ring for the guys wire by cutting the area related to the water trap will reduce the Flare Stack Strength so affect to Structure Capabilities to withstand the critical load or not?

8. PROBLEM BOUNDARIES

The problem Boundaries used in this research are as follows:

a. The structure Element that is to be observed focuses on checking on the area that has been modified,
b. Modeling and Structure Analysis will be done using a Numeric Application with Linear Static Basis,
c. Wind Load Modelling that works on the Guye Wire Installation Location (Pad Eyes) refers to the maximum load that worked on the Wind Load Form. This data was collected from Flare Stack-related Vendor

9. RESEARCH METHODOLOGY

The method that used in this research is as follows:

a. Collecting and interpreting Flare Stack Inspection Report,
b. Literature Study refers to Operating System from Flare Stack,
c. Interpretation Drawing from Flare Stack Vendor,
d. Numeric Analysis for knowing structure sensitivity from strength decrease because of corrosion,
e. Height limitation Element for Riser structure that makes on modeling and making a simulation with a variety of heights so that could choose one model with a certain height that no effect to the critical load.

10. ANALYSIS AND STUDY

In this research, to know structure response related to connecting area modification will be simulated using finite basis commercial application. Flare stack is modeled with finite element theory using plate elements. For simplification of the geometry model, only 1.0 m length below and 8.8 m length above the connection ring for guy wire is modeled (with a total length 9.8 m). To idealize the behavior of the structure, fixities are defined as a boundary condition on the bottom of the structure geometry (boundary limit area) and max. The tension load of the guye wire is idealized as a point load on the contact area between the pad eye and guye wire.

Part of the connection ring will be modified by removing upright plate side that is suspected for the potential risk of water trapped so that produces corrosion in a certain time. Although the design already has a drain hole in the related area, water trapped potential due to a clogged drain hole has happened. The Ringside will be cut off as shown in Figure 10.

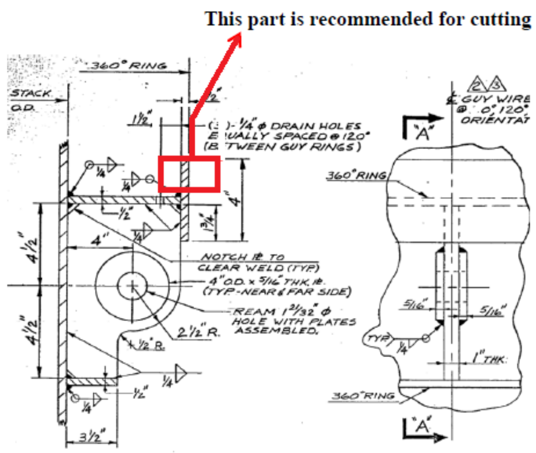


Figure 10. Detail dwg for Connection Ring for Guy Wire

Structure modeling as a whole on the software could be seen in Figure 11, while the magnified view of the connecting ring area could be seen in Figure 12.

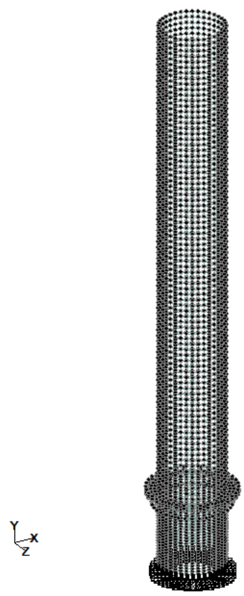


Figure 11. Flare stack model

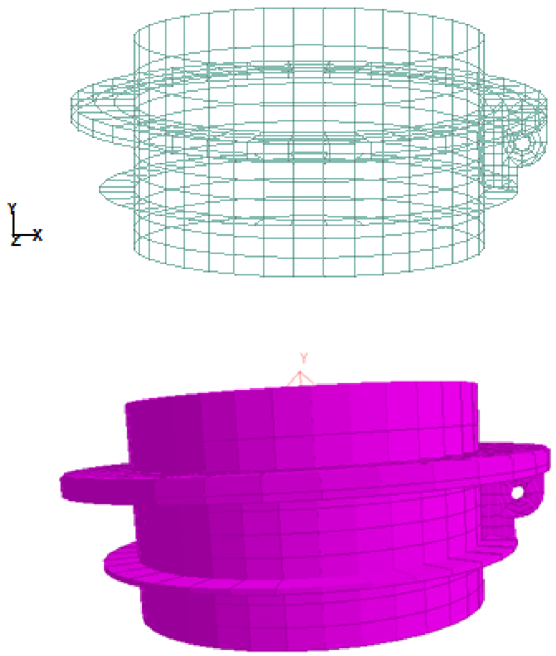


Figure 12. Detail model for area connection ring

Material thickness is modeled as the latest inspection data as shown in Table 2 and Figure 13.

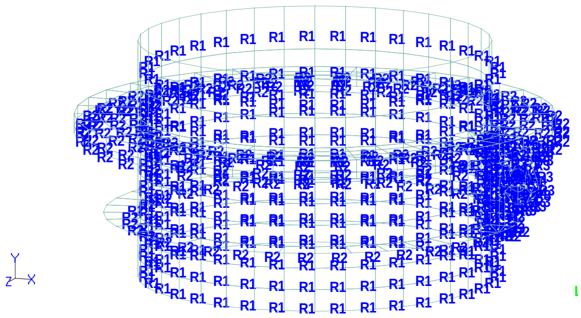


Figure 13. Material thickness on STAAD Model

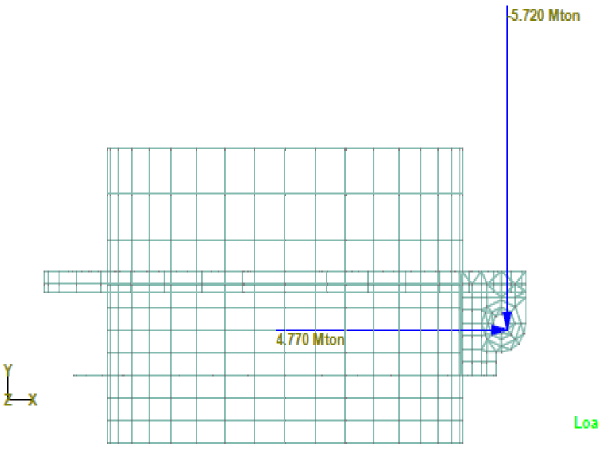
Table 4. Material thickness

No	Ref.	Properties	Remark
1	R1	Plate 6.35mm	Stack Riser
2	R2	Plate 12.7mm	Connection Ring
3	R3	Plate 25.4mm	Pad Eye
4	R4	Plate 40.1mm	The total thickness of the Cheek plate area

The steel plate used on the flare stack structure element is A-283 Gr.C Material with a melting point of 205 MPa. The size of the Tension Ratio that happened could be counted and solved using the equation as follows:

$$Max\ Stress\ Ratio = \frac{Max\ Stress}{0.8Fy} \qquad (2)$$

To simplify tension load modeling on guy wire, the load shall be converted to being Global Coordinate system in Horizontal & Vertical Directions (Global X Dir and Global Y Dir).
Guye wire angle = 50.19˚
Horizontal load dir. (Glob. X) = 4.77 ton
Vertical load dir. (Glob. Y) = 5.72 ton



Gambar 14. Tension Load Model

Tabel 5. Load Combination

LC No	Load Combination	Condition
11	**DL + 0.7 Wx**	**Operation**

Where:
DL : Dead Load (Self Weight of structure)
W : Wind Load on X Direction (Tension Load on guy Wired)

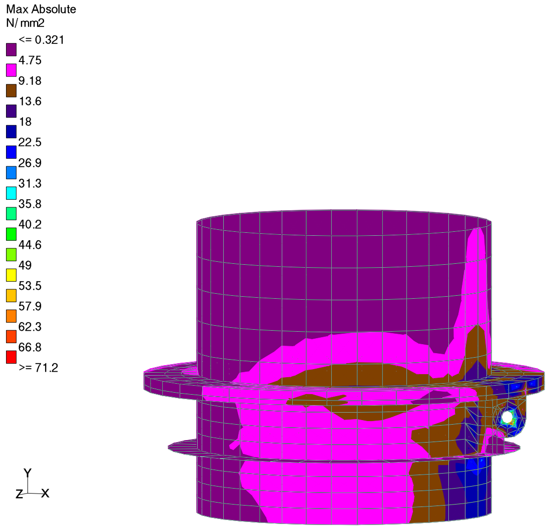


Figure 15. Stress contour under critical load

Table 6. Maximum stress ratio under critical load

No	Member Profile	Max. stress (Mpa)	Max. stress ratio	Status
1	Stack Riser	27.6	0.168	Accepted
2	Connection Ring	27.4	0.167	Accepted
3	Pad Eye	71.2	0.434	Accepted

Based on the simulation (Figure 15 and Table 6) obtained Tension Load Value on the Riser side area is 27.6 MPa, on the connecting area is 27.4 MPa, and on pad, the eye area is 71.2 MPa. Max. The stress Ratio on a maximum state on the pad eye area is 0.434 so this value is still below boundaries if compared with the allowable stress ratio of about 1.0.
As the result based on the simulation, structure performance is still good even when the structure has a maximum outside load while geometry modification from the connection ring for guye wire is done.

11. CONCLUSION

The research result shows that modifying the geometry shape from connecting the ring to the guye wire still gives good performance for the structure capabilities when handling the critical outside load. The maximum tension that happened around pad eye area is 71.2 MPa with a maximum stress ratio are 0.434, and the value is still far enough from the tension ratio that is allowed, 1.0.

Thus to conclude with modified the connection ring for guye wire to avoid corrosion risk could be done or performed without decreasing structure performance on hold the critical outside load

REFERENCES

[1] Allowable Stress Design and Plastic Design, Specification For Steel Buildings, June 1, 1989

[2] ASCE 7-10, Minimum Design Load and Associated Criteria for Buildings and Other Structure

[3] Laporan inspeksi, team Operation & Integrity Department, VICO Indonesia

[4] Manual book, STAADPro

[5] Peraturan Menteri Energi dan Sumber Daya Mineral Republik Indonesia No.17 tahun 2021 tentang Pelaksaan Pengelolaan Gas Suar pada Kegiatan Usaha Minyak dan Gas Bumi

[6] Sulardi. (2021). Inspeksi Teknik Instalasi Flare Stack Industri Migas dan Selanjutnya. Petrogas. Volume 3, Nomor 2, Agustus. 20-28.

[7] Sulardi. (2021). Resetting Verticality Flare Stack dengan Pengaturan Tegangan Guy Wire. Info Teknik. Vol.22 No.1. 117-126.

[8] Satiawan, Rahayu. (2022). Simulasi Evaluasi Korosi pada Struktur Flare Stack. Konstruksia, Vol 13, No 2, 146-154.

[9] Bassey, N. (2008) Gas Flaring: Assaulting Communities, Jeopardizing the World Rights Action in Conjunction with the Federal Ministry of Environment at Reiz Hotel, Abuja. 10-11 December.

[10] Ohio Epa (2014), GasFlare, Sistem keamanan dan pembebasan ,division of air pollution control, November.

[11] Amirsyam, Siregar, and Zain. (2018). Analyze The Excess of The Pressure on The Flare Stack Using The Gas Combustion Method. Journal of Mechanical Engineering, Manufactures, Materials and Energy, Vol.2 (2) Dec. 67-72.