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Stress Analysis on Emergency Pipeline from Flare to Pressure Vessel

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***Abstract*— Failure of piping system due to pipe damage due to process is very diverse and needs to be studied related to this case. Failure of piping system due to pipe damage due to process is very diverse and needs to be studied related to this case. This study focuses on the analysis of emergency piping systems connected to flares and pressure vessels. This aims to analyze the piping system which includes stress value analysis to ensure the stress value due to sustained load, occasional load and thermal expansion load. The methods used simulation with commercial software. The results of the research show that a 6 in emergency pipe line requires a minimum of 2 supports with a maximum allowable pipe span of 36.967 ft. The pipe flexibility value of 0.00146 is still below the limit of 0.02582 set by ASME B31.3. Stress analysis due to sustained, occasional, and thermal expansion loading shows the highest values respectively of 2572.5 lb/in² (12.6% of the permit limit), 1294.0 lb/in² (18.9% of the permit limit for seismic loads), 595.0 lb/in² (2.2% of the permit limit for wind loads), and 23921.3 lb/in² (49.3% of the permit limit).**

Keywords— Flare, Pressure vessel, Stress analysis, Sustained, Occasional, Thermal expansion

.I. INTRODUCTION

More than 98% of buried oil and gas transmission pipelines are impacted, even though these pipelines are designed, constructed and protected, they are subject to environmental attack, external damage, coating peeling, inherent material defects, ground movement and instability, and third-party damage after being used in the field [1].

A very important component in the transfer of fluids in the process in the industry is the piping system, which is well designed to play a vital role in maintaining the safety and protection of the entire facility. This ensures that the transfer of fluids will run safely and efficiently [2].

Stress analysis is the basis for piping design that discusses the suitability of routing, hangers, nozzle loads, and supports to withstand various stresses with the provision of not exceeding the permitted limits. Process and power piping systems, stress analysis will evaluate the mechanical behavior of piping that occurs under regular loads such as thermal stress and internal pressure, as well as stresses caused by earthquakes, wind, special vibrations, and water hammer [3].

The basis of the stress category is three categories, namely primary, secondary and operational stress, where the results showed that the maximum stress for dual, primary and secondary stress is 87.7% of the allowable stress [4].

The high vibration of reciprocating pump category for pipeline system to supply oil will seriously impact the safe operation of the equipment and the pipeline system. And the resonance occured between pipe and the equipment will influence damage. Therefore modal and vibration analysis will be required for pipeline system [5].

At the temperature and mass of the installed pipe must be considered in various operating conditions and loads on the LNG process piping system when the analysis is carried out. Stress analysis is combined in various conditions of continuous load, intermittent load, and expansion load. Stress is assessed using finite element analysis based on beam elements that represent the behavior of the piping. The components of the piping system, namely valves, expansion joints, and supports will be represented in the finite element method while CAESAR-II, software analyzes finite elements [6].

The fluid contained in the piping system has high pressure and temperature. The piping system design uses a 6 diameter pipe with schedule 40 material A312-TP304 with a design temperature value of -149.8 F and a design pressure of 274.9 psig. According to Chamsudi [7], piping systems connected to static equipment are included in the critical line category if viewed based on temperature graphs, so the calculation of pipe stresses [8], [9] connected to flares and pressure vessels needs to be analyzed. Stress and flexibility analysis is part of the value of designing and implementing piping systems. To avoid failure, calculations must be made so that the piping system can operate properly when operating loads occur.

Several studies have discussed stress analysis, determining the location and type of support, pipe scraping and static stress analysis including stress due to continuous loads, stress due to thermal, occasional loads

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and stress due to nozzle loads based on the permitted stress values of ASME B31.3 [10].

This aims to analyze the piping system which includes stress value analysis to ensure the stress value due to sustained load, occasional load and thermal expansion load is still below the allowable stress value based on ASME B31.3 [11] occur on flares and pressure vessels.

II. METHOD

Perform maximum allowable pipe span calculations [12], stress analysis calculations on pipes that occur on flares and pressure vessels. This analysis was carried out on the emergency line piping system which is connected to the flare as follows.

A. Identification

Problem identification is carried out in the piping system with the aim of identifying the main problem by raising issues regarding critical line pipe analysis and stress analysis of emergency line pipes, where the piping system is said to be good if the stress value in each load case is still within the allowable case range permitted based on ASME B31.3.

B. Taking data

Data is obtained for analysis from primary and secondary data. Primary data is taken from data related to calculation formulas for stress in piping systems, calculation of maximum distance between supports based on limitation of stress, calculation of maximum distance between supports based on limitation of deflection. Secondary data comes from technical specification data including Isometric Drawing, Line List, P&ID, and Identification data.

C. Data Processing

Data processing is carried out by following up the data collection process.

1. Modeling of the piping system to be analyzed using pipe stress analysis software.
2. Calculation of the maximum allowable pipe span value on emergency line pipes and determining support placement.
3. Comparison of the number and location of pipe supports with the calculation results of the maximum allowable pipe span based on limitation of deflection and limitation of stress. If the number and location of supports are appropriate then the analysis stage can be carried out, if they are not suitable the number and location of supports can be re-determined.
4. Analyze the stress on the emergency line pipe with the new support design using pipe stress analysis software and check the analysis results referring to ASME B31.3.
5. Comparison of the stress value on the emergency line pipe against the permit limits based on ASME B31.3. If the stress value meets the criteria then the analysis can be continued at the next stage, if it is not suitable the number and location of supports can be re-determined.

III. RESULTS AND DISCUSSION

Isometric drawings contain general information about the piping system, such as drilling direction, distance between pipe supports, pipe size (nominal pipe size), pipe height information, and several others. In this research, there is an emergency pipeline connected to the flare and pressure vessel as represented in Figure 1.

This calculation is used for the distance (span length) and amount of support required in the pipeline design. In calculating the distance between supports, unit variables are required which are found in Table 1 regarding pipe specifications and Table 2 regarding load specifications.

TABLE 1.

PIPING SPECIFICATION DATA

Parameter	Units	Value
NPS	In	6
Pipe Schedule	-	STD
Outside Diameter (OD)	In	6.625
Inside Diameter (ID)	In	6.066
Wall Thickness	In	0.280
Pipe Density	lb/in³	0.289
Specified Min Yield Strength (SMYS)	Psi	30000
Specified Min Tensile Strength (SMTS)	Psi	75000
Modulus Elasticity (E)	Psi	27990000
Moment of Inertia (I)	in^4	28.100
Section Modulus (Z)	in^3	8.500

TABLE 2.

LOAD SPECIFICATION DATA

Parameter	Units	Value/Description
Fluid Density	lb/in³	0.000521317
Operating Temperature	F	149
Design Temperature	F	-149.8
Operating Pressure	Psi	137.9
Design Pressure	Psi	274.9

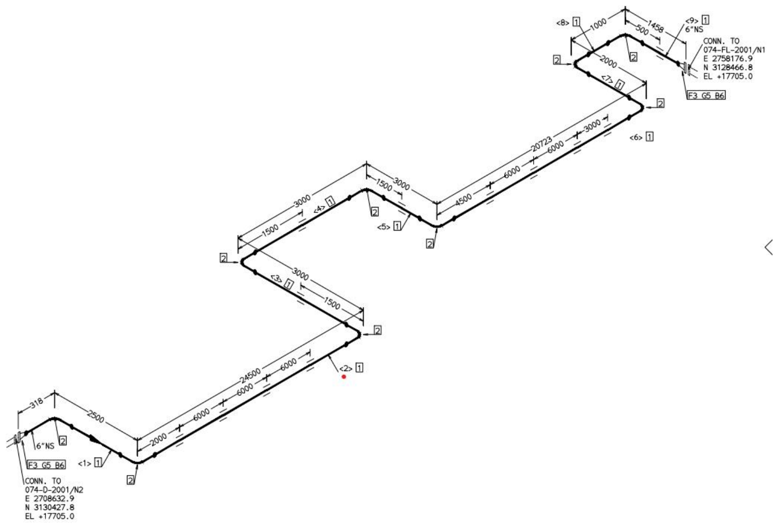

Figure. 1. Piping Isometric

Modeling of emergency pipelines in the TAR-8 area with a size of 6 in has been carried out using stress analysis software, then stress analysis is carried out due to sustained loading on each segment with load case 5 (L5). This analysis is carried out to determine whether the stress that occurs meets the permit limits in ASME B31.3. The calculation results are in Table 3, analysis of the effects of sustained loading on the piping system [13]. Figure 2 is a graph of the results of stress analysis due to sustained loading.

From the results of stress analysis calculations using software due to sustained load on the emergency pipeline piping system, it can be seen in the table and graphic image of the analysis results. The results of the stress analysis show that the pipeline system is still below the stress permit limit determined based on ASME B31.3. From the results of the output report, the highest stress value (marked in yellow) is at node 320-330 at 2572.5 psi with a ratio to allowable stress of 12.6%. Judging from Figure 2, the maximum value due to sustained load occurs in the area where there is support, where the support receives the greatest load. This load is caused by the weight of the pipe, the weight of the fluid which weighs it continuously. However, the maximum stress value still meets the pipe allowable stress requirements based on ASME B31.3.

TABLE 3.
STRESS ANALYSIS RESULTS FOR SUSTAINED LOAD

Segmen	Node	Code Stress (psi)	Allowable Stress (psi)	Ratio (%)	Result	Piping Code
19	130-135	2372.3	20000.0	11.9	Pass	B31.3
27	150-155	2385.0	20000.0	11.9	Pass	B31.3
31	160-165	2353.2	20000.0	11.8	Pass	B31.3
50	300-310	2332.5	20000.0	11.7	Pass	B31.3

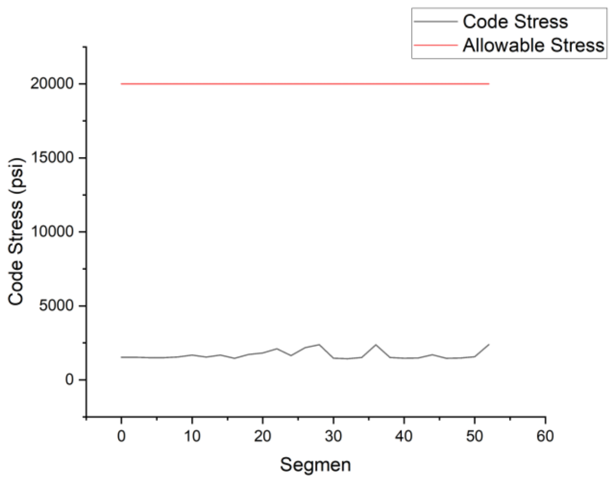

Figure. 2. Graph of Stress Analysis Results Due to Sustained Load

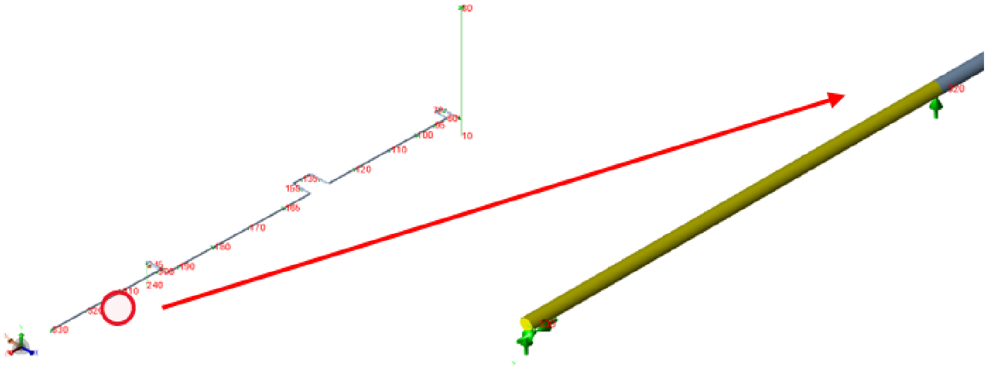

Figure. 3. Modeling on Node 320-330

A. Analysis of Occasional Load (Seismic)

Stress analysis due to occasional loading is carried out after modeling the emergency pipe route using software. Next, stress analysis was carried out on each segment with load case 14 (L14) (OCC = L6 – L3). Occasional loads here are added to seismic loads. Analysis is carried out to determine whether the stress that occurs meets the permit limits in ASME B31.3 [5]. The results of stress analysis calculations due to occasional loading are in Table 4 for the piping system. Figure 4 is a graph of the results of stress analysis due to occasional load.

TABLE 4.

STRESS ANALYSIS RESULTS FOR OCCASIONAL LOAD (SEISMIC)

Segmen	Node	Code Stress (psi)	Allowable Stress (psi)	Ratio (%)	Result	Piping Code
17	143-141	1276.1	26600.0	4.8	Pass	B31.3
18	141-130	1210.4	26600.0	4.6	Pass	B31.3
29	158-159	1215.7	26600.0	4.6	Pass	B31.3
31	160-165	1294.7	26600.0	4.9	Pass	B31.3
50	300-310	1294.0	26600.0	18.9	Pass	B31.3

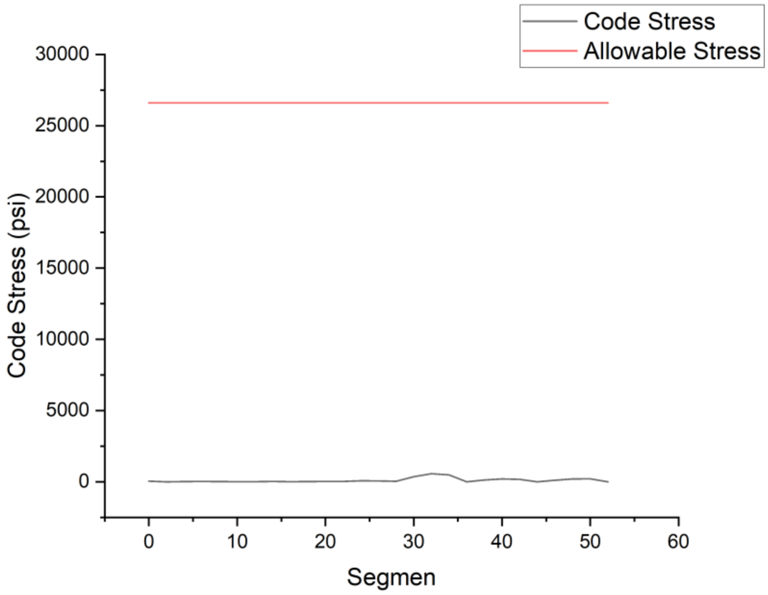

Figure. 6. Stress Analysis Result Due to Occasional (Wind Load)

From the stress analysis calculation using software due to occasional loading which is added to the wind load value on the emergency pipeline piping system in the TAR-8 area, it can be seen in the Table 5 and graphic image of the analysis results in Figure 6. The results of the stress analysis show that the pipeline system is still below the stress permit limit determined based on ASME B31.3. The highest stress value (marked in yellow) is at node 159-160 at 595.0 psi with a ratio to allowable stress of 2.2%. The location of the highest stress occurs in the bend area which causes a large load that occurs in the bend area. The highest stress value occurs at the bend section (elbow) due to the high flexibility of the bend which results from the ability of the cross section to curve when subjected to bending or internal pressure. However, the maximum stress value obtained still meets the pipe allowable stress requirements based on ASME B31.3.

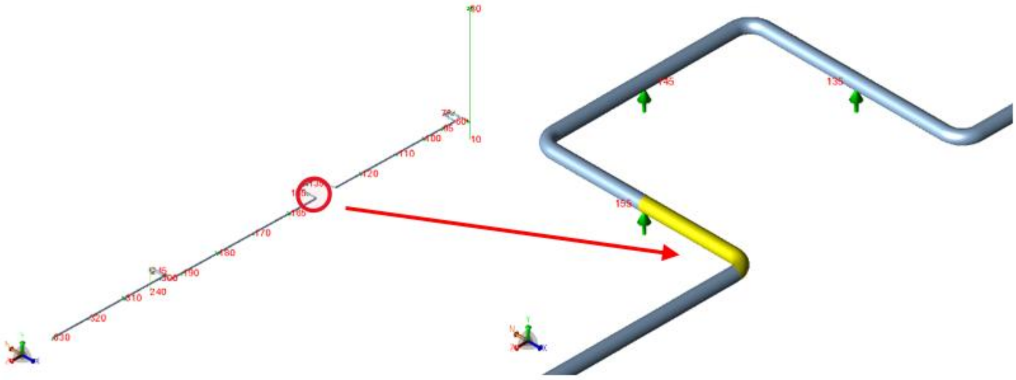

Figure. 7. Modeling on Node 159-160

B. *Stress Analysis due to Thermal Expansion Load*

Stress analysis due to thermal expansion loading was carried out after modeling the 6 inch emergency pipeline piping system using a combination of load case 30 (L30) (EXP = L3 – L5). Thermal load (thermal expansion load) is a load that occurs as a result of the temperature of the flowing fluid and the properties of the pipe material which can cause elongation of the pipe (expansion). The calculation results are in Table 6 of the stress analysis due to thermal expansion loading on the piping system and in Figure 8 is the result of a graphical analysis of the results of the stresses that occur due to thermal expansion loading.

TABLE 6.

STRESS ANALYSIS RESULTS FOR THERMAL EXPANSION LOAD

Segmen	Node	Code Stress (psi)	Allowable Stress (psi)	Ratio (%)	Result	Piping Code
21	144-140	17002,7	48519,7	35,0	Pass	B31.3
25	153-154	16604,2	48519,1	34,2	Pass	B31.3
45	268-269	20954,6	48522,8	43,2	Pass	B31.3
46	269-270	23921,3	48509,3	49,3	Pass	B31.3
47	270-280	23459,6	48535,3	48,3	Pass	B31.3

From the stress analysis calculation using software due to thermal expansion loading on the emergency pipeline piping system in the TAR-8 area, it can be seen in the table and graphic image of the analysis results. The results of the stress analysis show that the pipeline system is still below the stress permit limit determined based on ASME B31.3. The highest stress value (marked in yellow) is at node 269-270 at 23921.3 psi with a ratio to allowable stress of 49.3%. The location of the highest stress occurs in the bend area where previously there were pipe branches and other pipe components that added to the load. This load is caused by the weight of the pipe, the weight of the fluid and the weight of components other than the pipe such as flanges which are a continuous burden and the flexibility of the elbow has a geometry that allows it to be more flexible than straight pipe sections, so it is more easily deformed when thermal expansion occurs

Figure 9 shows a diagram rotation of the savonius wind turbine with additional fin to variation of diameter disturbing cylinder ds/D = 0.1; 0.2; 0.3; 0.4 at wind speeds of 5 m/s, 6 m/s, 7 m/s. From the graph, it can be seen that the larger the diameter disturbing cylinder can be the higher RPM. The largest RPM value is obtained at ds/D 0.4 or 16 cm at each wind speed, the RPM value at a wind speed of 5 m/s is 322, then at a wind speed of 6 m/s the RPM is 345, and at a wind speed of 7 m/s. s produces an RPM of 378.

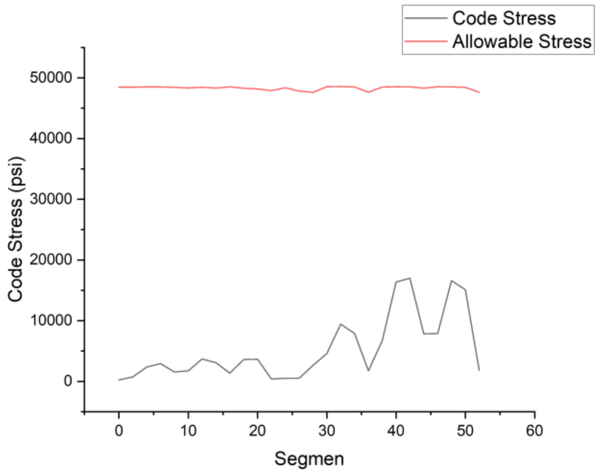

Figure 8. Graph of Stress Analysis Result Due to Thermal Expansion Load

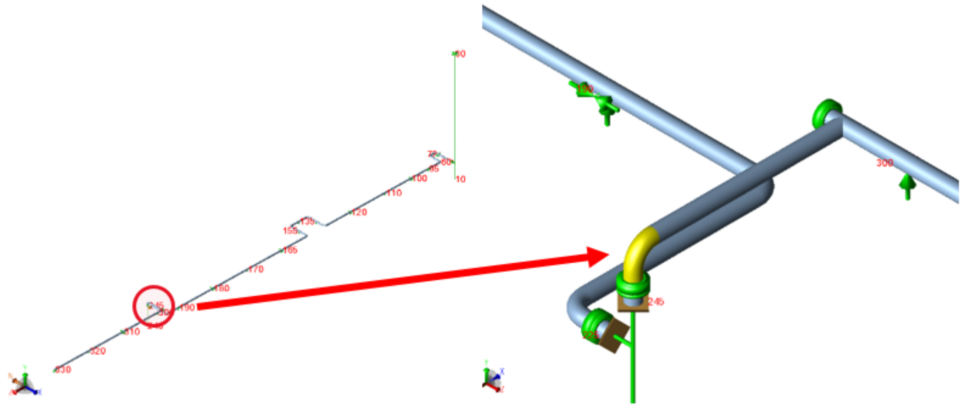

Figure 9. Modeling on Node 269-270

IV. CONCLUSION

The maximum allowable pipe span value for an emergency pipe line with a size of 6 in on a straight pipe is 36.967 ft and with a known length, the number of supports required for this line number is 2 supports (minimum). The pipe flexibility value of 0.00146 is still below the limit of 0.02582 set by ASME B31.3. Stress analysis due to sustained, occasional, and thermal expansion loading shows the highest values respectively of 2572.5 lb/in² (12.6% of the permit limit), 1294.0 lb/in² (18.9% of the permit limit for seismic loads), 595.0 lb/in² (2.2% of the permit limit for wind loads), and 23921.3 lb/in² (49.3% of the permit limit).

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REFERENCES

[1] National Energy Board, "Stress Corrosion Cracking on Canadian Oil and Gas Pipelines." MH-2-95, NEB, Calgary, Alberta, Canada, 1996.
[2] Prabhu Kishore, N., & Prabhu, S. (2018). Modeling and Stress Analysis of Pump Piping. IOP Conference Series: Materials Science and Engineering, 455(1). https://doi.org/10.1088/1757-899X/455/1/012100.
[3] Bisht, S., & Jahan, F. (2014). An Overview on Pipe Design using caesar II. International Journal on Emerging Technologies, 5(2), 114–118.
[4] Wu, X., Lu, H., & Wu, S. (2015). Stress analysis of parallel oil and gas steel pipelines in inclined tunnels. SpringerPlus, 4(1), 1–25. https://doi.org/10.1186/s40064-015-1453-1
[5] Wu, X., Lu, H., Wu, S., Huang, K., Wan, J., Li, W., & Liu, Z. (2014). Stress analysis of reciprocating pump pipeline system in oil station. Journal of Chemical and Pharmaceutical Research, 6(7), 2026–2032.
[6] Hwang, S. Y., Kim, M. S., & Lee, J. H. (2020). Thermal stress analysis of process piping system installed on lng vessel subject to hull design loads. Journal of Marine Science and Engineering, 8(11), 1–16. https://doi.org/10.3390/jmse8110926.
[7] Chamsudi. (2005). Diktat : Piping Stress Analysis, Jakarta: PT. Rekayasa Industri.
[8] Kannappan, S. (1986). Introduction to Pipe Stress Analysis. U.S.A.: John Wiley & Sons, Inc.
[9] Pratama, P. T. (2004). Training of Analysis Basic of Pipe Stress. Jakarta: PT Tijara Pratama.
[10] Krismantono. W (2020). Stress Analysism of Critical Line Pipe Dari Tie-In Point Existing to Inlet North Acid Gas Flare Study Case Project Refinery Unit in Oil Treatment Company. Diploma Thesis Politeknik Perkapalan Negeri Surabaya.
[11] ASME B31.3, (2022). Process Piping ASME Code for Pressure Piping, 831 AN INTERNATIONAL PIPING CODE®. ASME B31.3-2022: Process Piping (ASME Code for Pressure Piping, B31). American Society of Mechanical Engineers.
[12] Agustinus, D. (2009). Introduce to Piping Stress Analysis. Jakarta: Entry Agustino Publisher.
[13] Coade. (1998). Pipe Stress Analysis Seminar Notes. Houston, Texas: Coade Inc