Stress Analysis of Land Subsidence Effect on Header Pipe 12 Inch in LPG Station Semarang

Taufik Fajar Nugroho, Ede Mehta Wardhana, Ribhi Naufal Azmi

Abstract- in the process of distributing LPG to all regions in Indonesia, LPG stations have an important role. In operation, LPG stations may have hazards caused by environmental conditions such as pipe fatigue (fatigue) due to geotechnical forces or failure of components in the system. Research case of piping systems used pipe stress analysis. The purpose of this analysis is to know the deflection of the pipe, the loads that occur by the pipe, and the safety of the pipe and its support. This analysis refers to the code or standard ASME B31.3 where the stress analysis is performed using software. In the process of pipe modeling, there are variations of loading such as pressure load variation, wall thickness and elevation of soil degradation value. From the results of calculation and simulation pipe stress analysis using software can be seen that header pipe 12 inch at LPG station of Semarang is NOT stress, so it is safe to be use. The thickness of the pipe allowed for to be unstable when the operating pressure is greater than 0.15 inch, and the operating pressure allowed for the pipe to be unstable at a thickness of 0.4 pipe (schedule 40) is less than 725 Psi (50 Bars).

Keywords— ASME B31.3, LPG station, Pipe stress analysis, Software

I. INTRODUCTION

LPG stations becomes an important role in the distribution process to all regions in Indonesia with the main function of LPG stations are recipients, mixers, hoarders, and distributors. In its operation, LPG stations has potentially hazards caused by environmental conditions such as fatigue due to geotechnical forces or failure of components in the piping system. Pipe fatigue may occur due to soil conditions in the city of Semarang that often occurs land subsidence. Other hazards that may occur in LPG stations are fires and explosions that can cause damage to company assets and casualties.

In an industry basically wants in every production process takes place, the system runs well and in accordance with predetermined standards [1]. Especially for the oil and gas industry such as in station LPG of Semarang which is not apart from the use of piping systems on production processes that occur, planning a good piping system has been affect the results of the process.

Piping is a pipeline that connected between lines in a production plan. Piping has the function to flows fluid from one place to another. The fluid inside the pipe can be either gas, water and vapour that has a certain temperature [2]. Because in general the pipe is made by metal and according to its characteristics, the pipe has been expand when heated and has been shrink when cooled. Any incident expanding or shrinking from the pipe, has been cause the increase or reduction of pipe length from its original size, on a horizontal scale. The design of a good and secure piping system is needed to ensure continuity of the process and to ensure usage life of the piping system

in accordance with the design cycle. The safe parameter is when the pipe is able to withstand their weight under loading conditions due to the pressure and weight of the pipe and loading of temperature effects. However, in fact there are still failures that occur in the piping system, either during installation or during operation. This may be affected by several loading factors that occur during the pipe already installed, may occur due to natural factors, loading when the pipe has not operated or loading when the pipe has operated. Therefore it is necessary to calculate the stress analysis to find out how much stress from the pipe that can be accepted by the pipe and supporting equipment in order to avoid failure.

Support is a tool used to withstand piping systems. Support is designed to be able to withstand various types of loading both due to the design and weight of the pipe (Sustain Load) and due to the temperature and pressure (Expansion Load). As a result of the loading it has been cause stress to be withheld by the Pipe Support. Because of the loading of thermal it has been occur expansion stress, as well as if the loading due to dead weight pipe and fluid it has been happen sustained stress [3]. The placement of support should take account of the movement of the piping system to the loading profile that may occur under various conditions. Because of the importance of this Support role, it is necessary to have a good plan for designing pipe support designs to be able to withstand the stresses of various loads [4-19].

Based on the above exposures, the authors has been analyze the pipe stress that is useful to determine the level of deflection of the pipe, the load received by the pipe, and the safety of the pipe and its supports. which refers to the code or standard ASME B31.3. Where stress analysis using software.

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International Journal of Marine Engineering Innovation and Research, Vol. 2(4), Sep. 2018. 261-268
(pISSN: 2541-5972, eISSN: 2548-1479)

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II. METHOD

The methodology is the basic framework that must be done to solve the problem in this case. In this chapter has been describe the steps taken during the process. Research carried out in this problem is taken at the LPG of Semarang station, research conducted is to analyze the stress of 12 inch header pipe. In general, the methodology used in this study is divided into 2 stages: (1) theoretical calculation of pipe stress analysis which refer to ASME B31.3 (2) pipe stress analysis using software.

A. Case Study

As has been explained before, the problem of land subsidence in Semarang city has the potential to cause fatigue in piping system at LPG station of Semarang, In Table 1 showing a result of measurement of soil decrease measured from elevation between support.

TABLE 1.
HIGH ELEVATION DATA SUPPORT ON HEADER PIPE 12 INCH

Identification No.	Result	Elevation
I1	0,822	2,620
I2	0,876	2,566
I3	0,895	2,547
I4	0,921	2,521
I5	0,940	2,502
I6	0,947	2,495
I7	0,948	2,495
I8	0,900	2,542
I9	0,869	2,573
I10	0,866	2,576
I11	0,887	2,555
I12	0,908	2,534
I13	0,938	2,504
I14	0,953	2,489
115	0,946	2,496

B. Collecting Data

The required data in this study case is piping design data and its path as a reference for calculation of piping stress analysis which has been be bypassed by LPG fluid. Pipe stress analysis that has been be done is calculation using standard code ASME B31.3 accompanied by piping system modeling on LPG pipeline using software.

TABLE 2.
SPESIFICATION DATA OF HEADER PIPE 12 INCH

No.	Specification of pipe	
1.	Type of pipe	ASTM A106 Grade B
2.	Length	143.46 m
3.	Outside Diameter	12.75 Inch
4.	Inside Diameter	11. 936 Inch
5.	Material of Pipe	Seamless Carbon Steel
6.	Wall Thickness	0.4059 Inch
7.	Modulus Elasticity	29.5×10^6 Psi
8.	Yield Strength	25000 Psi
9.	Tensile Strength	60000 Psi
10.	Dencity of Pipa	0.283 lb/in^3

Data collection and Information related to piping system analysis in LPG Station of Semarang include isometric drawings which have been described from image Pipping and Instrument Diagram (P & ID), Data about the maximum stress allowed on Pipping and Pipe support, Isometry Image, that is see the picture isometry to obtain the required data in calculations using software such as: Fluid Type, Line number, Rating Class, pipe size, Operation Pressure, Operation Temperature, Desaign Pressure, Temperature Desaign, Density, SCH, Thickness, Pressure Test, Insulation Code, Insulation Thickness , PWHT, NDE (Non Destructive Examination / Radiography Test). Matching Pipe support as the initial reference in entering the pipe span (distance between support) from it then obtained the distance pipe support used in the critical line, but from the calculation is not necessarily to be safe so it needs to be done several experiments to obtain optimal amount of support (Piping handbook). Determination based on experiments using software.

International Journal of Marine Engineering Innovation and Research, Vol. 2(4), Sep. 2018. 261-268
(pISSN: 2541-5972, eISSN: 2548-1479)

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TABLE 3.
SPESIFICATION DATA OF FLUID

No.	Specification of fluid	
1.	Type of fluid	Liquid
2.	Temperature	25^0C
3.	Pressure	6 Bar
4.	Dencity of fluid	600 /m^3

C. Piping Design Data

For piping design data is influenced by several parameters as follows: design flow rate, fluid type, maximum and minimum operating pressure, temperature, pipeline and pipe specification used.

D. Calculation of pipe stress analysis

The first process starts with finding parameters associated with the system. These parameters are the design data of a pipe and its material specifications, then look for pipeline system path. Because the pipeline in the analysis is piping system so the calculation analysis using code ASME B31.3. From pipe stress analysis that has been get maximum allowable stress in accordance with the standard code used. Maximum allowable stress is the maximum value limit of the safest pipe stress allowed to be used.

- Longitudinal Stress
  Longitudinal stress is a stress that is parallel to the longitudinal axis (SL) or axial stress. The value of stress is tested positive if the stress that occurs is the tension and negative stress if the stress is a compressive stress. Longitudinal stress on the pipe system is caused by axial forces, pressure in pipes, and bending.
- Hoop Stress
  This stress is caused by pressure in the pipe, and is positive if stress splits the pipe in half
- Radial Stress
  This stress is the same as the radial axis, and this stress is compression stress if pressed from the inside of the pipe due to pressure gauge, and in the form of tensile stress if inside the pipe there is a vacuous pressure
- Torsional Stress
  This stress occurs due to the moment that works on the pipe that resulted in a shift angle to the axis of the pipe, the working moment can be a moment or force that resulted in the torsion.

E. Modeling using software

Modeling using the required data software is the same as the data used during pipeline stress calculation. After the modeling and entry data of some piping design parameters has been be obtained a piping model and stress analysis report on the pipeline. Modeling made include:

- Input node number (from node to node)
- Pipe dimension
- Length of pipe orientation (x, y, and z coordinates)
- Pipe material
- Standard code input

- Temperature and pressure

Then in the piping system is described piping components contained in the line, such as valve, flange, elbow, reducer, tee. In incorporating these piping components as well, the weight of these components and their dimensions are taken into account. Inserting nodes in the pipe system. Enter the type of pipe support that has been be used and pipe span (distance support). Analyze the voltage, which occurs on each pipe support with variations of loading using software. In piping operations there are various types of loads that occur in the piping system.

After modeling, then matching the data obtained with Allowable stress that is the yield stress limitation on ASME B31.3 [5], if there is one pipe support that has a voltage exceeding the limit of allowance it has been be re-modeling pipe support. Nozzle load analysis in the form of Style and Moment on equipment that is on Vessel and Pump using software. Then matching the data obtained with the allowable stress data in the Vendor Code, if there is one nozzle that has a voltage exceeding the limit allowance it has been be re-modeling pipe support.

F. Checking Error on Modeling

Physical modeling checks for misfiring (coordinate orientation, length)
Running error check from software, to find out errors and warnings on modeling

G. Pipe Stress Analysis

The amount of load that occurs with the selected code (ASME B31.3) with the software has been adjusted and equated to the type used in the piping installation in the case specified in the plan. The result of the analysis is the amount of stress of the pipe.

III. RESULTS AND DISCUSSION

Calculation of pipe stress is used to find out how much stress received by the pipe by using formula based on standard ASME B31.3. The calculation of pipe stress starts from the 8-inch piping that flows the LPG fluid from the storage tank to the header pipe 12-inch, then continued from the header pipe 12-inch to the pump. The calculations that must be done to determine the stress of the pipe are as follows:

- Internal area of pipe
- Axial Forces
- Cross section of pipe
- Axial stress
- Bending stress
- Torsion stress

- Longitudinal stress

The value of longitudinal stress should not to be exceeded from standard ASME stress b31.3. Stress on the piping system is caused by static and dynamic loads categorized into normal stress and shear stress [3]. To define the direction of the normal stress a pipe principle axis is made perpendicular to each other. Stress is one of the problems that must be passed in a piping system. Therefore stress that occurs in the piping system can be grouped to anticipate the excessive stress on the system in two categories as follows normal stress and shear stress.

TABLE 4.
RESULT OF CALCULATION PIPE STRESS USING STANDARD ASME B31.3

Pipe No.	Sustained Load				
	Axial Stress (Psi)	Bending Stress (Psi)	Internal Stress (Psi)	Total Stress (Psi)	Allowable Stress (Psi)
8"-114	518	12400	583	13502	20000
8"-124	518	7936	582	9037	20000
8"-134	518	12342	582	13443	20000
8"-144	518	7658	582	8760	20000
12"-102	617	3377	683	3458	20000

Based on the **Table 4** results of pipe stress calculations we can know that with the same diameter pipe has been get the value of axial stress and internal stress is the same because the value of pressure on the same pipe. but the value of bending stress has been be different because it is influenced by the length of the pipe. so the value of total axial stress, internal stress and bending stress has been affect the total pipe stress analysis that should not exceed maximum allowable stress that is 20000 psi. Based on the total value of stress on each piping system in **Table 4** there is no overstress so it is safe to use.
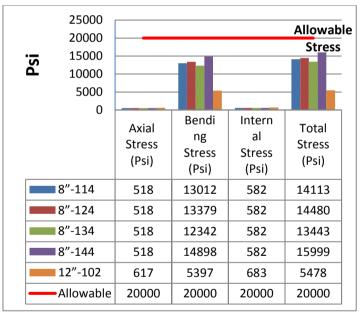

	Axial Stress (Psi)	Bending Stress (Psi)	Internal Stress (Psi)	Total Stress (Psi)
8"-114	518	13012	582	14113
8"-124	518	13379	582	14480
8"-134	518	12342	582	13443
8"-144	518	14898	582	15999
12"-102	617	5397	683	5478
Allowable	20000	20000	20000	20000

Figure. 1. Pipe Stress Analysis using standard ASME B31.3

Based on the graph in **figure 1** we has been know that the different stress values of some piping systems. This is caused by factors such as pipe length, pipe diameter, pressure and temperature.

Based on the standard formula asme b31.3 that the smaller the value of the cross-sectional area has been make the greater the stress value. The highest pipe stress is on the pipe no. 8"-144 because the pipe is longer than the other pipe, because it is longer than the pipe has been also be heavier.

TABLE 5.
RESULT OF CALCULATION PIPE STRESS USING SOFTWARE

Pipe No.	Sustained Load						
	Axial Stress (Psi)	Bending Stress (Psi)	Torsion Stress (Psi)	Hoop Stress (Psi)	Max Stress Intensity (Psi)	Total Stress (Psi)	Allowable Stress (Psi)
8"-114	887,5	5098,5	964,5	1817,5	6018,8	14786,8	20000
8"-124	887,5	5091,9	964,5	1817,5	5992	14753,4	20000
8"-134	887,5	4326,3	818,2	1817,5	5245,9	13095,4	20000
8"-144	887,5	5872,9	1112,3	1817,5	6780,2	16470,4	20000
12"-102	922,4	1046,8	18,9	1887,2	2019,3	5894,6	20000

In this case, the calculation pipe stress is using software Caesar II V 8.0. By using this software we can know at the point where the maximum pipe stress has been occurred. So that if there is stress, it has been be easy to redesign the piping system in order to avoid the stress.

Same as the calculation based on code standard ASME B31.3. The results of calculations using software Caesar II V 8.0 in **Table 5** is also still within safe limits to use because of the total stress value are below maximum allowable stress.
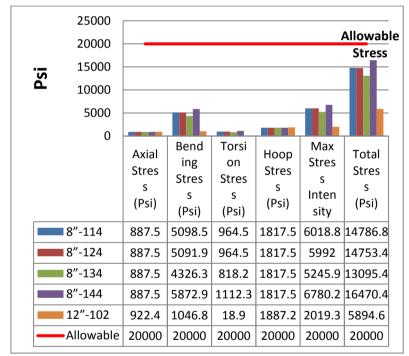

	Axial Stress (Psi)	Bending Stress (Psi)	Torsion Stress (Psi)	Hoop Stress (Psi)	Max Stress Intensity	Total Stress (Psi)
8"-114	887.5	5098.5	964.5	1817.5	6018.8	14786.8
8"-124	887.5	5091.9	964.5	1817.5	5992	14753.4
8"-134	887.5	4326.3	818.2	1817.5	5245.9	13095.4
8"-144	887.5	5872.9	1112.3	1817.5	6780.2	16470.4
12"-102	922.4	1046.8	18.9	1887.2	2019.3	5894.6
Allowable	20000	20000	20000	20000	20000	20000

Figure. 2. Pipe Stress Analysis Using Software

Based on the graph in **figure 2** we has been know the difference of stress value with calculation based on ASME B31.3. this occurs because the placement of support on ASME B31.3 calculations is the same length of distance between support. so the highest value of pipe stress is pipe no.8"-144 while the lowest pipe value is pipe no.8"-134, different from the **figure 1** on pipe no. 8 "-144 is the lowest value of pipe stress.

Because the value of pipe stress analysis using the calculation method based on standard code ASME B31.3 and using software showed good results because it is still

below the allowable stress value that has been specified, so now has been find to the extent of how many operating pressure of the pipes it has been happen stress. To know the effect of operating pressure variation has been be tried with value of operating pressure as in the **Table 6** on model 1 is 362 psi, model 2 is 725 psi, model 3 is 1087 psi and model 4 is 1450 psi.

TABLE 6.
RESULT OF CALCULATION PIPE STRESS USING VARIATION OF PRESSURE OPERATION

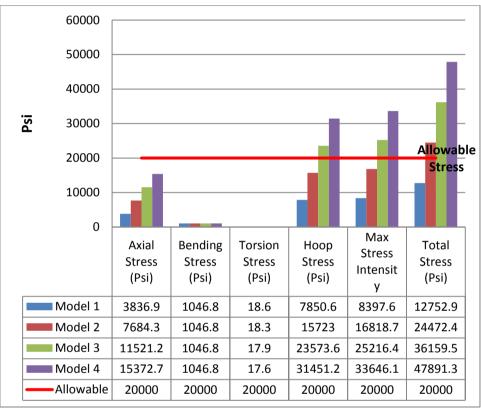| Pipe	Sustained Load						
	Axial Stress (Psi)	Bending Stress (Psi)	Torsion Stress (Psi)	Hoop Stress (Psi)	Max Stress Intensity (Psi)	Total Stress (Psi)	Allowable Stress (Psi)
Model 1	3836,9	1046,8	18,6	7850,6	8397,8	12752,9	20000
Model 2	7684,3	1046,8	18,3	15723,0	16818,7	24472,4	20000
Model 3	11521,2	1046,8	17,9	23573,6	25216,4	36159,5	20000
Model 4	15372,7	1046,8	17,6	31454,2	33646,1	47891,3	20000

Figure. 3. Pipe Stress Analysis Using Variation of Pressure Operation

Based on **figure 3** we has been know that the greater the value of the operating pressure has been be the greater the value of axial stress. then for bending stress and torsion stress tends to remain because the material from the pipe is made of the same material that is carbon steel. The same as axial stress, hoop stress has been also increase along with the increase in the value of operating pressure. so it can be concluded that the greater the value of operating pressure has been be the greater the value of pipe stress that occurs. in this case, the pipe has been experience stress at the operating pressure above 725 Psi (50 Bars).

TABLE 7.
RESULT OF CALCULATION PIPE STRESS USING VARIATION OF WALL THICKNESS PIPE

Pipe	Sustained Load						
	Axial Stress (Psi)	Bending Stress (Psi)	Torsion Stress (Psi)	Hoop Stress (Psi)	Max Stress Intensity (Psi)	Total Stress (Psi)	Allowable Stress (Psi)
Model 1	11030,2	6950,6	160	22103,7	22237,4	40244,5	20000
Model 2	2154	1757,4	36,6	4351,1	4482,9	8299,1	20000
Model 3	1167,9	1186,7	22,5	2378,6	2510,5	4755,7	20000
Model 4	788,8	971,6	17,0	1620,0	1805,4	3397,4	20000

In this case has been be calculated pipe stress analysis with variation wall thickness of existing pipe in **Table 7.** Variation of wall thickness of this pipe is to know what limit of wall thickness minimum of pipe which allowed to this pipe is not experience overstress. so in model 1 calculated with the wall thickness of the pipe is 0.15 inch, model 2 is 0.25 inch, model 3 is 0.35 inch and model 4 is 0.45 inch.
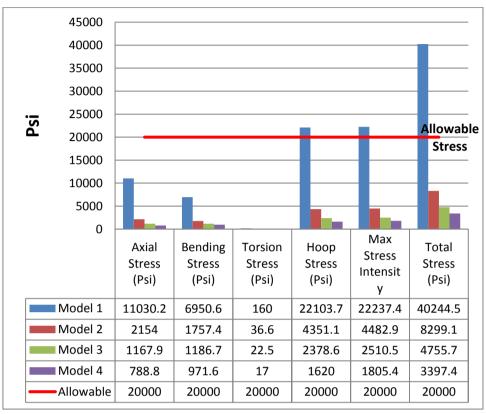
	Axial Stress (Psi)	Bending Stress (Psi)	Torsion Stress (Psi)	Hoop Stress (Psi)	Max Stress Intensity	Total Stress (Psi)
Model 1	11030.2	6950.6	160	22103.7	22237.4	40244.5
Model 2	2154	1757.4	36.6	4351.1	4482.9	8299.1
Model 3	1167.9	1186.7	22.5	2378.6	2510.5	4755.7
Model 4	788.8	971.6	17	1620	1805.4	3397.4
Allowable	20000	20000	20000	20000	20000	20000

Figure. 4. Pipe Stress Analysis Using Variaton of Wall Thikness Pipe

Based on **figure 4** we know that differences arise from various models. The largest axial stress value is model 1 which has a very low wall thickness of the pipe is 11030 Psi, This shows the smaller thickness of the pipe has been be greater value of axial stress. Similar things appear on the hoop stress is the smaller the wall thickness of pipe, the greater the value of hoop stress. However, for bending stress and torsion stress does not change significantly because the pipe is made of the same material. So, it can be concluded that the wall thickness of the pipe should not to be less than 0.25 inch that the pipe does not happen stress.

IV. Conclusion

From the result of analysis that has been done about pipe stress analysis on header pipe 12 inchi at Station LPG of Semarang can be concluded as follows :

- From the calculation of pipe stress analysis and simulation using software can be seen that the header pipe 12 inch in station LPG of Semarang does NOT experience stress, so it is safe to use. The wall thickness allowed for the pipe to be unstable when the operating pressure is greater than 0.15 inch, and the operating pressure allowed for the pipe to be unstable at the thickness of 0.4 pipe (schedule 40) is less than 725 Psi (50 Bar).
- The value of land subsidence at LPG station of Semarang is still in low category, so it does not affect stress on pipes significantly. Stress on header pipe 12-inch has been occur if the pipe span (distance between support) is greater than 25 m and the ground drop elevation is greater than 1 inch (25.4 mm) with operating pressure and fixed temperature.
- The piping system designed in accordance with the data provided by station LPG of Semarang which has been standardized according to ASME B31.3 piping standard can be concluded safe and does not require redesign with notes at some nodes of high stress bending but not critical stage (still within material safe limits).

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