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Study on pipe deflection by using numerical method

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Abstract. Piping systems are widely used in a refinery or oil and gas industry. The piping system must be properly designed to avoid failure or leakage. Pipe stress analysis is conducted to analyze the loads and critical stress occurred, so that the failure of the pipe can be avoided. In this research, it is analyzed the deflection of a pipe by using Finite Element Method. The pipe is made of A358 / 304SS SCH10S Stainless Steel. It is 16 inches in size with the distance between supports is 10 meters. The fluid flown is Liquid Natural Gas (LNG) with the range of temperature of -120 ° C to -170 ° C, and a density of 461.1 kg / m 3. The flow of LNG causes deflection of the pipe. The pipe deflection must be within the permissible tolerable range. The objective is to analyze the deflection occurred in the piping system. Based on the calculation and simulation, the deflection is 4.4983 mm, which is below the maximum limit of deflection allowed, which is 20.3 mm.

1. Introduction

Piping systems are widely used in flowing fluids from one to another component. They are used in simple mechanical applications, such as draining system and agricultural drainage pumping system [1][2]. They are also used in industrial applications such as in refineries, oil and gas industries. For most industrial purposes, the piping system must be properly designed to avoid a crack, failure or leakage [3] [4][5][6][7] [8].

In designing a piping system, the behavior of the piping system due to loading should be understood while considering the design codes and standards. The behavior of piping systems includes displacement, acceleration, voltage and force. In the world of engineering, it is known as pipe stress analysis [3]. Pipe stress analysis is conducted to determine the critical stress and loads that occur in the pipeline so that the failure of the pipe can be avoided.

In Arun LNG plant in the city of Lhokseumawe in Aceh province, there are many piping systems from the upstream sector to the distribution sector. The piping system has a very long track and is supported by slipper type support. The fluid flown inside the pipe is Liquid Natural Gas (LNG), with the range of temperature is from -120 ° C to -170 ° C and the density is 461.1 kg / m^3. The flow of LNG becomes a burden for the pipe that causes the deflection. This research analyzes the effect of pipe deflection by using Finite Element Method. The deflection of the pipe must be within the permissible tolerable range.

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2. Method

2.1. Material specification

The pipe analyzed is located in Unit 68 of the LNG piping system (Loading Unit) as can be seen in Figure 1. It is a ten meters pipe supported by slipper pedestals at both edges with a flange in between. The model of the analyzed pipe can be seen in Figure 2.



Figure 1. Analyzed piping system.

The material of the pipe is Stainless Steel A358 / 304SS SCH10S (the detail is shown in Table 1). In addition, the code of Flange material is A182-F304, CL 150, SCH10S, WN-RF and the code of bolt material is A320-B8 and A194-BT, (FOR 4"-150LB FLG JOINT). For the gasket, the material code is COMP-ASB RF gaskets 1.5mm LGIBTAZ T # 1000 Harrow COMP - NON-ASBESTOS / REINFORCED PIPE, ISO LB (T = 1, 5 - 2.5mm THK).

Table 1. Chemical composition Stainless Steel A358 / 304SS [9].

Grade	Chemical Composition %					Tensile Test		
	C	Si	Mn	P	S	Ultimate Tensile Strength (N/mm^2)	Yield Strength (N/mm^2)	Elongation
304	0.08	0.75	2.00	0.045	0.030	586	241	55

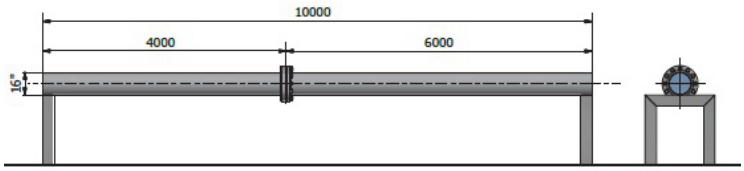


Figure 2. 2D model of the pipe.

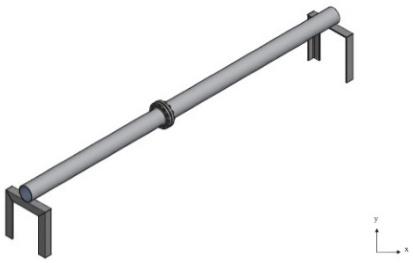


Figure 3. 3D model of the pipe.

2.2. Modeling

The pipe is modeled by using Autodesk Inventor. The 3D model is shown in Figure 3. The simulation is conducted by using ANSYS. The material properties inputted in the modeling process is shown in table 2.

Table 2. Material Properties [9].

Property	Value	Unit
Poisson's Ratio	0.26	N/A
Modulus Elasticity Tension	193	GPa
Mass Density	8.03	g/cm^3
Yield Strength	290	MPa
Ultimate Strength	621	MPa

3. Result and Discussion

3.1. Analytical Analysis

The deflection is calculated analytically based on ASTM (American Society of Testing Materials) pipe standards and then analyzed numerically. The diameter of the analyzed pipe is 16 inches, pipe density is 8.03 g/cm^3, the temperature inside the pipe is -162 ° C, and the pressure inside the pipe is 9.0 MPa.

Table 3. Analytical result

Property	Value
Weight of LNG	559,48 N
Weight of the Pipe	4948,889 N
Total Weight of Pipe dan LNG	5508,369 N
Moment of Inertia	1.276 x 10^{-4}m^4
Weight per Unit	550,83 $^{N}/_{m}$
Modulus of Elasticity	193 x 10^{9} $^{N}/_{m^2}$

The deflection of the pipe is obtained initially by calculating the weight of LNG and the pipe. Afterward, the moment of inertia and the modulus of elasticity is calculated. The result is tabulated in Table 3. Based on the result, the deflection (y) is calculated:

$$y = -\frac{5ql^4}{384\,EI}$$

$$= -\frac{5 \,.\, 559{,}8 \,.\, (10)^4}{384 \,.\, (193\, x\, 10^9) \,.\, 1{,}275 \,.\, 10^{-4}}$$

$$= -\frac{5 \,.\, 550{,}83 \,.\, (10)^4}{9{,}44928 \text{ x } 10^9}$$

$$= \mathbf{-2{,}91\ mm}$$

$$y \approx \mathbf{-3\ mm}$$

Whereas:

y = Deflection
q = Weight per unit
l = Length of pipe
E = Modulus of elasticity
I = Moment of Inertia

Based on the book "Steel Pipe: A guide for Design and Installation, 4th Ed." By AWWA Staff, the maximum allowed the limit of flexible lined and coated = 5% of the outer diameter of the pipe [10].
The maximum amount of deflection allowed is

$= 5\% \; x \; \text{OD}$
$= 5\% \; x \; 406 \text{ mm}$
$= 20{,}3\text{mm}$

Whereas:
OD = Outer Diameter of Pipe

Compared with the deflection calculation result, which is 3 mm, the occurred deflection is below the allowed deflection, which is < 20.3 mm that the construction is safe.

3.2. Numerical Analysis

3.2.1. Mesh

The process of meshing is performed on the entire range of pipe components with automatic meshing. The mesh application is shown in Figure 4 and 5.

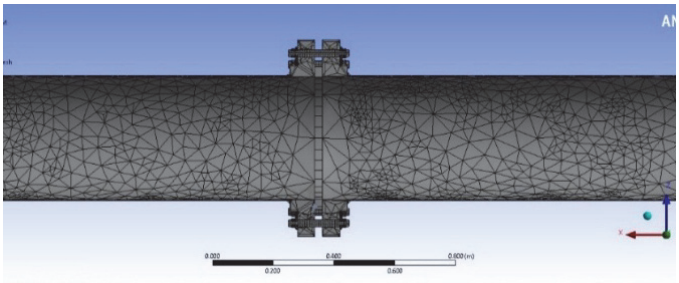


Figure 4. Meshing In the middle section of the pipe.

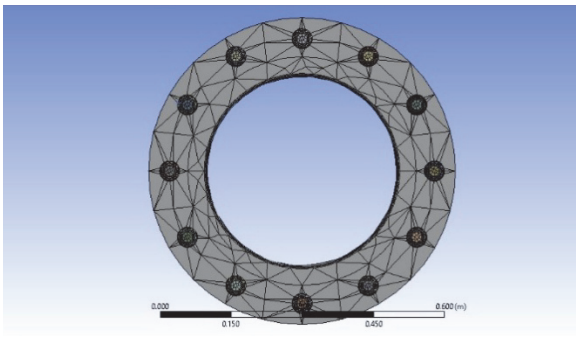


Figure 5. Meshing on the cross-section view of the pipeline.

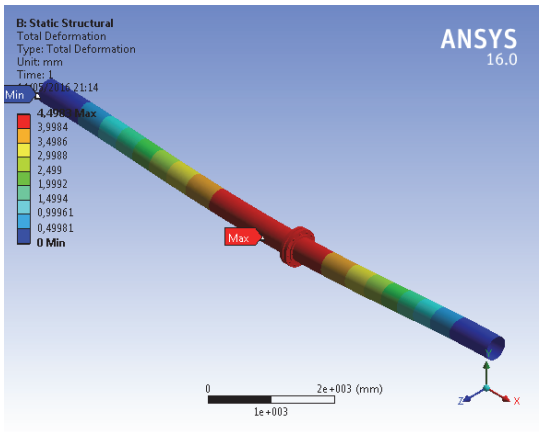


Figure 6. Deflection with maximum load on the pipe.

3.2.2 Deflection

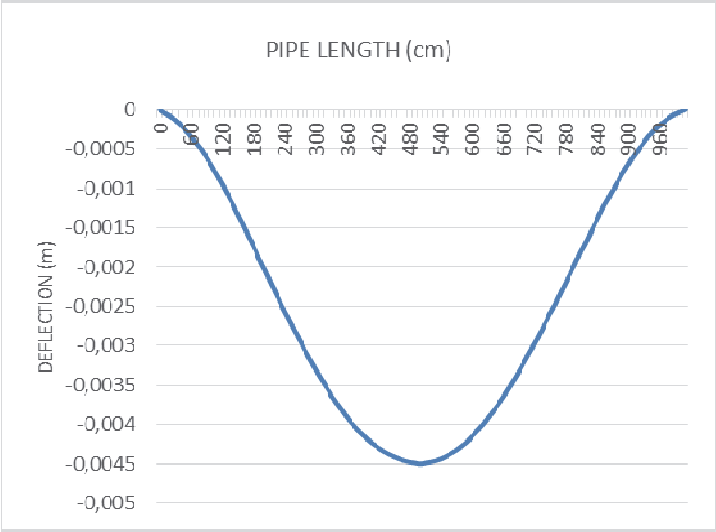
The result of the deflection simulation for maximum load on the pipe can be seen in Figure 6. The image shows a color change generated due to voltage conditions caused by deflection in the pipe, it

appears that the maximum deflection occurs in the middle of the pipe, with the deflection of **4.4983 mm.** The deflection is within the allowed limits.

Figure 6 and 7 show the value of the largest deflection in the middle of the pipe with a distance of 500 cm from the edge. The deflection is **4.4983 mm.** The smallest visible deflection is at the end of the pipe, which is **0.49981 mm.**



(a)



(b)

Figure 7. (a) Pipe deflection on the XY axis. (b) The deflection the pipe that occurs in every 10 cm on the XY axis.

3.2.3 Stress

The simulation results of maximum equivalence stress (Von Misses) that occur on the pipe can be seen in Figure 8. The maximum equivalence is 100.39 MPa. The maximum shear stress is 38.435 MPa. The shear stress result can be seen in Figure 9.

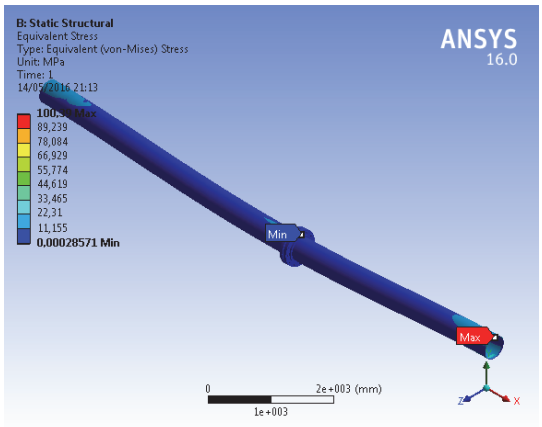


Figure 8. Equivalence stress (Von Misses) that occurs in the pipeline**.**

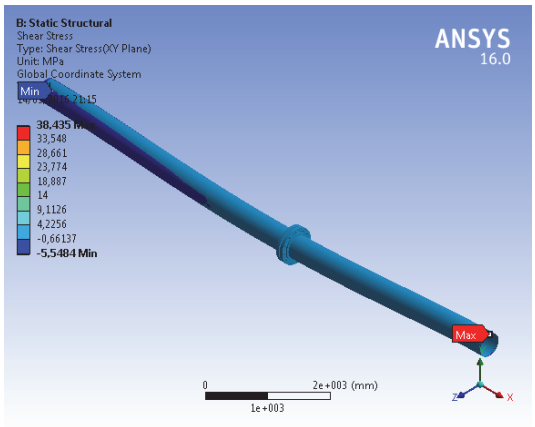


Figure 9. The shear stress result**.**

The simulation result *of normal stress* can be seen in Figure 10. The figure shows that the maximum normal stress is 79.176 MPa.

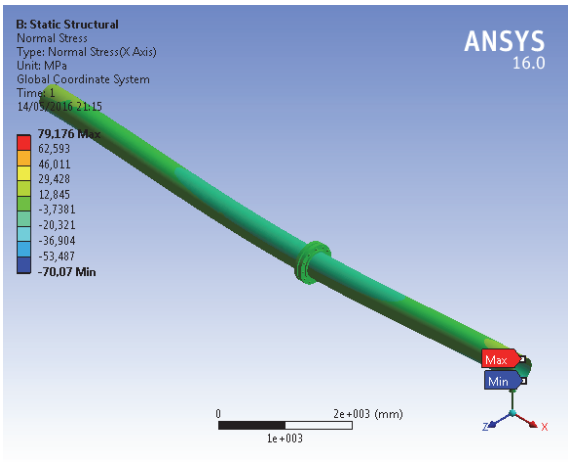


Figure 10. Normal stress result.

4. Conclusion

Based on the calculation and simulation, the occurred deflection is safe as it is below the maximum deflection limits, which is 20.3 mm.

The result of the pipe deflection numerical calculation, by the distance between the pedestals of 10 meters, shows the deflection of 4.4983 mm. The maximum equivalence values stress (Von Misses) is 100.39 MPa. The maximum shear stress is 38.435 MPa, and the maximum Normal Stress is 79.176 MPa.

References

[1]. Munarak A Z, Maulana M I, Syuhada A 2016 Design and testing of fish drier system utilizing geothermal energy resource in Ie Suum, Aceh Besar, *AIP Conf. Proc.* **1717** 050011-1 – 050011-7
[2]. Syuhada A, Mubarak A Z, Maulana I 2016 Study of hybrid power system potential to power agricultural water Pump in Mountain Area, *AIP Conf. Proc.* **1717** 050013-1 – 050013-8
[3]. Thesis UMY 2016 Sistem Perpipaan https://thesis.umy.ac.id/datapublik/t25134.pdf. (Accessed 26 January 2016) (in Indonesian)
[4]. Husaini, Mubarak A Z and Qadri N 2016 Analysis of deformation effect on the Support of Steel Pipe A106 by using Finite Element Method *Proceedings of SNTR III* 118-125
[5]. Husaini, Mirza, Ali M and Mahmud M N 2014 Analisis kegagalan daerah lasan pipa stainless steel sebagai media reboiler pabrik pupuk *Prosiding SNTTM XIII* 223-228 (in Indonesian)
[6]. Tsyss V G, Sergaeva M Yu 2016 Finite element analysis of discharge antivibrational pipe stress state of the Piping System Flexible Joint *Procedia Engineering* 251-257
[7]. G Mathan, N Siva Prasad 2012 Study of dynamic response of piping system with Gasketed Flanged Joints using Finite Element Analysis *International Journal of Pressure Vessels and Piping* 28-32
[8]. Husaini, and Kishimoto K 2001 Mixed mode fracture behavior of PC/ABS blends, Proceedings of SPIE - The International Society for Optical Engineering **4317** 111 - 116
[9]. AK Steel 2016 A354/304SS www.aksteel.com. (Accessed 27 January 2016)
[10]. AWWA Staff 2004 *Steel Pipe: A guide for Design and Installation, 4th Ed*