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Analysis of Pipe Lay Barge Hafar Neptune Capability in Pipelaying Operation at Offshore North West Java Oil and Gas Field

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ABSTRACT

When pipelaying activity is carried out, the most influential factor is the significant wave height. In this final project, the maximum significant wave height allowed for the PLB during the pipelaying process was analyzed with the variation of pipe diameters, which are 8 inches, 10 inches, and 12 inches; variations in the direction of coming waves namely 0°, 45°, 90°, 135°, and 180°; and stinger angle variations. First, static analysis was performed using OFFPIPE software Then, Pipe Lay Barge (PLB) Hafar Neptune modelled with MOSES software and validated with ABS MODU codes. The output was RAO from the Hafar Neptune PLB. Next, dynamic analysis was performed with OFFPIPE software, where the input is static analysis, RAO of Pipe Lay Barge Hafar Neptune, and JONSWAP wave spectrum formulation. The result of the analysis was the significant wave height that could hit the PLB when pipelaying is 3 meters for all pipe diameter variations. For variations in the direction of the wave data, the maximum Hs were 3 meters for 0 ° and 180 °, 2.5 meters for 45 °, 1.5 meters for 90 ° and 135 °.

Keywords: *Underwater pipeline installation, S-Lay, Pipe Lay Barge.*

1.INTRODUCTION

Underwater pipeline is one of the most economical means of fluid transportation in this era [1]. The main function of an underwater pipeline is to transport hydrocarbons taken from the reservoir to onshore storage or processing facilities. One of the most frequently transported fluids using underwater pipelines is natural gas. Thus, the underwater pipeline is one of the main components in the operation of the oil and gas industry in Indonesia. The need for underwater pipelines is quite high considering the current situation where oil and gas reserves have begun to be excavated in offshore areas. Before an underwater pipe can be used, it must first be carried out underwater pipe installation activities. There are several types or methods of underwater pipe installation such as s-lay, j-lay, reel lay, and towing. However, in Indonesian waters especially in the north Java sea, the most used installation method is the s-lay method.

In the process of underwater pipeline installation, there are several activities carried out. However, one of its main activities is pipelaying. Pipelaying is a part of an underwater pipeline installation where piping and levelling activities on the seabed are carried out. At Indonesian water, especially the *Offshore North West Java* (ONWJ) area, the s-lay method is used very often. S-lay refers to an installation method of offshore pipelines, which the pipeline starts to assemble in the firing line on the lay vessel, where a section of pipes with a certain length are aligned and welded, then the welds are tested and inspected using an automated ultrasonic test (AUT), and the field-joints are coated [2]. To carry out this activity, a certain vessel is needed. Several types of vessels that can be used for pipelaying activities such as pipe-laying semisubmersibles, pipe laying ships and barges, pipe-laying reel ships, and towing or pulling vessels [3]. The focus on this Final Project is pipe-laying ships and barges, the specifics used are Pipe Lay Barge (PLB).

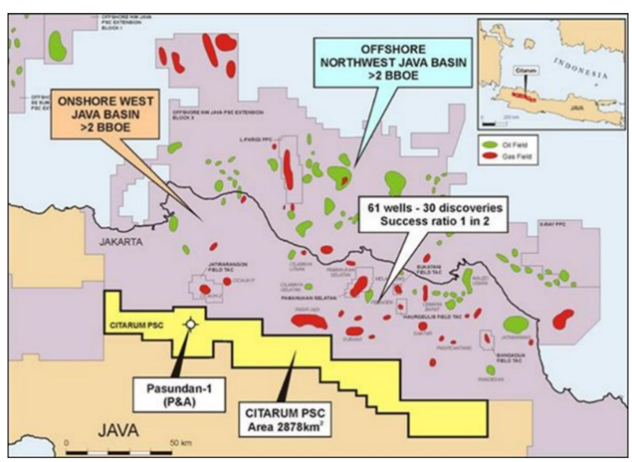

Figure 1. Offshore North West Java Oil and Gas Field

When pipelaying is carried out, several factors that affect the capability of PLB. What is meant by capability here is the ability of PLB to install pipes safely. One of the factors that influence is the maximum wave height allowed at the time of pipe installation. On the pipelay barge, the pipelines are normally supported by multiple discrete roller supports and tensioners, and the tensioners can be modelled by the tension winch element, which is attached to the vessel and the pipe to ensure that the effective tension fed from the tensioner is applied to the top end of the pipeline [2]. If the curvature is wrong or the roller does not support the pipe properly, the pipe will be subjected to stress that exceeds the requirement which can cause buckling of the pipe. Furthermore, if the tension applied by the tensioner machine is insufficient, it will affect the curvature of the pipe in the sag bend and the moment of the stinger. This will cause breaking to the pipeline [4]. Finally, if the wave height on the PLB during installation exceeds its safe limit, pipelaying must be stopped and the pipeline must be abandoned. Normally, this process is done by installing an Abandonment-Head and then lowering this head to the bottom of the sea with an attached buoy for easy identification and retrieval [5]. This process will affect project scheduling and potentially cause losses for the company.

2. DATA AND RESEARCH METHODOLOGY

2.1 Data

The first step to carry out this final project was conducting a literature study then collecting some data required this final project research. Data needed includes:

a. Location

The location reviewed in this Final Project analysis is in the North West Java Offshore Oil and Gas Field, Lima field, MGRID 3-4.

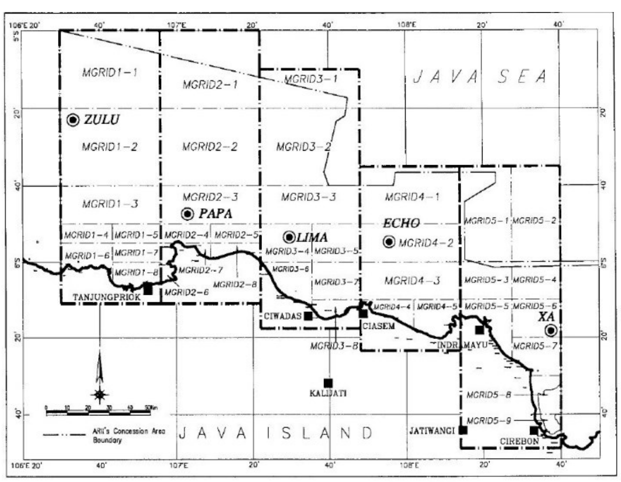

Figure 2. MGRID 3-4 Lima Field ONWJ

b. Metocean Parameter

Table 1. Metocean Parameter MGRID 3-4

Parameter	Reset Periode (Year)			
Item	Notation	Unit	1	100
Wave				
Significant wave height	Hs	m	1.8	3.6
Significant wave period	Ts	s	6.3	8.3
Spectrum	Jonswap			
Current				
0% Depth	V_0	m/s	0.79	1.22
50% Depth	V_{50}	m/s	0.48	0.57
100% Depth	V_{100}	m/s	0.42	0.43

The average depth in the MGRID 3-4 area is 23 meters below sea level. The significant wave height is 1.8 meters and the wave period is 6.6 seconds. The current velocity at the surface is 0.7 m/s and a maximum depth is 0.42 m/s. 1-year data is used because pipeline installation is a weather restricted operation [6].

c. Soil Data

The type of soil in the installation area is very soft greenish-grey clay. The longitudinal coefficient of fiction is 0.2. The coefficient of friction has its effect on the pipeline, especially on the bending moment. A higher coefficient of friction means higher bending moment on the pipeline [7].

d. Pipe Data

The pipe used in this analysis varies in diameter. In this thesis, the pipes used were 8 inches, 10 inches, and 12 inches in diameter.

Table 2. Pipeline Properties Data

Equipment	Value	Unit
8" Pipeline		
Material	API 5L Grade X52	
Outer Diameter	219.1.5	mm
Wall Thickness	12.7	mm
Corrosion Allowance	3	mm
SMYS	360	mPa
Steel Density	7850	Kg/m^3
Pipe Joint Length	12.2	meter
Poisson Ration	0.3	-
10" Pipeline		
Material	API 5L Grade X52	
Outer Diameter	273.05	mm
Wall Thickness	12.7	mm
Corrosion Allowance	3	mm
SMYS	360	mPa
Steel Density	7850	Kg/m^3
Pipe Joint Length	12.2	meter
Poisson Ration	0.3	-
12" Pipeline		
Material	API 5L Grade X52	
Outer Diameter	273.05	mm
Wall Thickness	12.7	mm
Corrosion Allowance	3	mm
SMYS	360	mPa
Steel Density	7850	Kg/m^3
Pipe Joint Length	12.2	meter
Poisson Ration	0.3	-

e. Pipe Lay Barge Data

Table 3. Principal Dimension of PLB Hafar Neptune

Parameter	Unit	PLB Hafar Neptune
LoA	m	85.34
B	m	24.34
D	m	3.25
H	m	5.5
Trim	Degree	0.5

The pipelay barge analyzed in this Final Project was PLB Hafar Neptune which had a length of 85.34 meters and a draft of 3.25 meters operating conditions / full load and a width of 24.34 meters. Meanwhile, the stinger used had a configuration of 6 rollers with a total length of 40,949 meters.

2.2 Static Analysis using OFFPIPE

The purpose of static analysis is to confirm all the laying equipment on the pipelay barge, such as roller configuration on the barge and stinger, stinger angle, and tension that was applied by the tensioner. Using OFFPIPE, all the stress that the pipe received during pipelaying can be seen. It requires certain inputs such as pipe properties, coating properties, pipelay barge data, roller configuration, stinger angle, and tension that was applied by the tensioner. The outputs are stress that the pipeline received and pipeline elevation during laying operation.

2.3 Vessel Modelling using MOSES

Modelling of Pipe Lay Barge Hafar Neptune was done using Moses software. The output was the hydrostatic properties of the modelled vessel. To validate the result of modelling, it is important to compare the hydrostatic properties of the modelled vessel and the hydrostatic properties from the original vessel. To do this, ABS MODU was selected to validate the result of modelling Pipe Lay Barge Hafar Neptune. After the validation completed, the modelled ship RAO would be seen as an output from MOSES.

2.4 Dynamic Analysis using OFFPIPE

To see how the external loads affected the pipe stress and to know the capability of Pipe Lay Barge Hafar Neptune in pipelaying operation, the dynamic analysis needed. The inputs of this analysis are all the input from static analysis, RAO of the pipelay barge, wave spectrum (JONSWAP) parameters, and time integration option. The results are wave height based on wave spectrum input and pipe stresses on dynamic conditions.

3. ANALYSIS RESULTS

3.1 Static Analysis Results

For static analysis, the output was total pipe stress that happened during installation which divided into several pipe nodes. OFFPIPE software was used to carry out this analysis as one of the most accepted software for pipelaying analysis in the industries [2]. The output from OFFPIPE was von misses stress. Here is the equation [8]:

$$\sigma e = \sqrt{\sigma h^2 + \sigma l^2 - \sigma h \sigma l + 3\tau hl^2} \quad (1)$$

Information:

σe = Equivalent Stress (MPa)
σl = Longitudinal Stress (MPa)
σh = Hoop Stress (MPa)
τhl = Tangential Shear Stress (MPa)

Allowable stress in the sag bend and stinger tip regions [8]:

$$\sigma e \leq 87\% \text{ SMYS} \quad (2)$$

a. Static analysis result for 8 Inch pipeline

Table 4. Static Analysis Result for 8 Inch Pipeline

OD	Water Depth	Lay Tension	Touch Down Distance	Stinger Angle	Max Pipe Stress	
					Overbend	Sagbend
mm	m	kN	m	deg	% SMYS	% SMYS
219.7	23	196.133	113.14	13.5	72	23

For pipes with a diameter of 8 inches, maximum pipe stresses were 72% SMYS on the over band area and 23% SMYS on the sag bend area with a touchdown distance of 112.1 meters.

b. Static analysis result for 10 Inch pipeline

Table 5. Static Analysis Result for 10 Inch Pipeline

OD	Water Depth	Lay Tension	Touch Down Distance	Stinger Angle	Max Pipe Stress	
					Overbend	Sagbend
mm	m	kN	m	deg	% SMYS	% SMYS
273.1	23	245.166	183.45	13.5	67	14

For pipes with a diameter of 10 inches, maximum pipe stresses were 64% SMYS on the over band area and 14% SMYS on the sag bend area with a touchdown distance of 151.99 meters.

c. Static analysis result for 12 Inch pipeline

Table 6. Static Analysis Result for 12 Inch Pipeline

OD	Water Depth	Lay Tension	Touch Down Distance	Stinger Angle	Max Pipe Stress	
					Overbend	Sagbend
mm	m	kN	m	deg	% SMYS	% SMYS
323.9	23	245.166	207.38	13.5	68	12

For pipes with a diameter of 12 inches, maximum pipe stresses were 68% SMYS on the over band area and 12% SYMS on the sag bend area with a touchdown distance of 165.61 meters.

3.2 Pipe Lay Barge Modelling

Here is a picture of the Hafar Neptune PLB modelling using MOSES software.

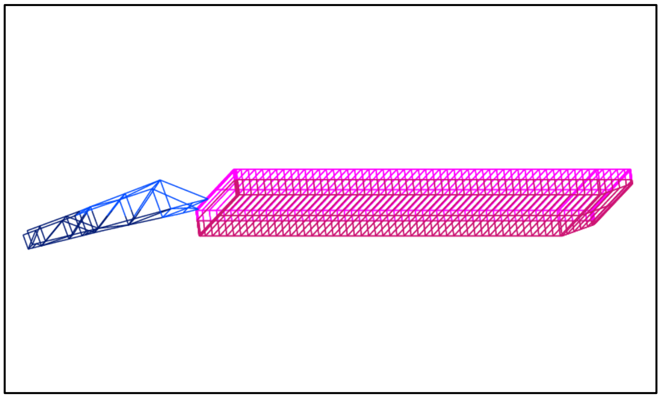

Figure 3. PLB Hafar Neptune Modelling using MOSES

3.3 Validation of Pipe Lay Barge Modelling

The validation of the Hafar Neptune PLB [9] is explained in Table 7.

Table 7. Validation of PLB Hafar Neptune Modelling

Parameter	Stability Booklet	Moses	Error	Criteria
Displacement	6707.63	6694.19	-0.20%	2%
LCB	41.312	44	6.51%	1% / 50 cm max
LCF	42.692	42.54	-0.36%	1% / 50 cm max
KMT	17.392	17.42	0.16%	1% / 5 cm max
BMT	15.74	15.77	0.19%	1% / 5 cm max
KML	194.278	193.22	-0.54%	1% / 50 cm max
BML	192.626	191.57	-0.55%	1% / 50 cm max

3.4 Pipe Lay Barge RAO

Pipelay barge characteristics and movement could affect pipe bending stress on pipelaying operation [10]. To get the response of the structure when arranged in a random wave, it is necessary to look for RAO (Response Amplitude Operator). RAO of a floating structure in translational motion (surge, sway, and heave) is given by the following equation [11]:

$$\text{RAO}\ (\omega) = \frac{\zeta k0\ (\omega)}{\zeta 0\ (\omega)}\ (\text{m/m}) \tag{3}$$

Information:

$\zeta k0\ (\omega)$= structure amplitude (m)

$\zeta 0\ (\omega)$ = wave amplitude (m)

As for the RAO for rotational motion (roll, pitch, and yaw), can be expressed with following equation [12]:

$$\text{RAO}\ (\omega) = \frac{\zeta k0\ (\omega)}{\zeta 0\ (\omega)} = \frac{\zeta k0}{(\omega^2/\,g)\zeta 0}\ (\text{rad/rad}) \tag{4}$$

RAO analysis was carried out at frequencies from 0 to 3 rad / s and at 6 degrees of freedom of the structure.

a. RAO on Surge Motion

Figure 4. PLB Hafar Neptune RAO on Surge Motion

b. RAO on Sway Motion

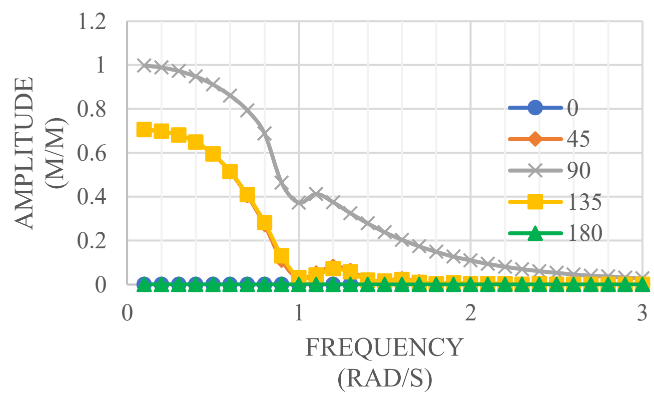

Figure 5. PLB Hafar Neptune RAO on Sway Motion

c. RAO on Heave Motion

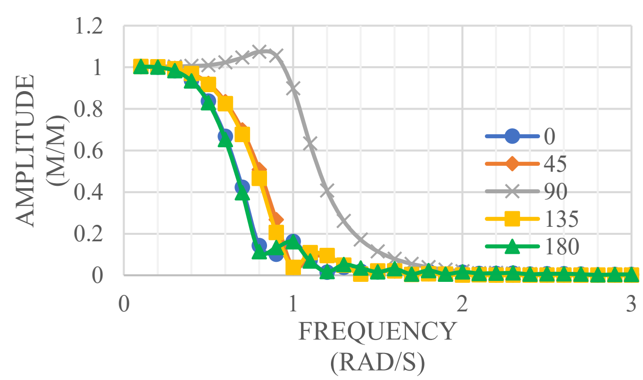

Figure 6. PLB Hafar Neptune RAO on Heave Motion

a. RAO Roll Motion

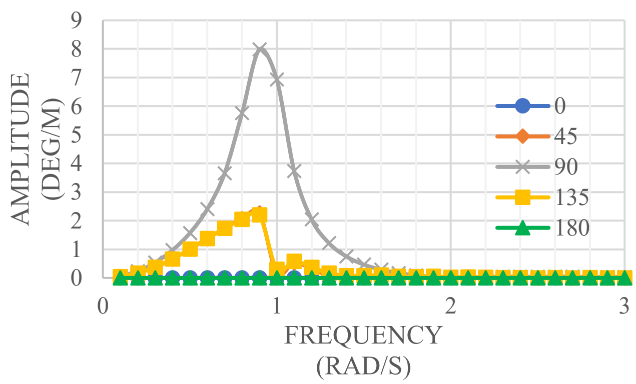

Figure 7. PLB Hafar Neptune RAO on Roll Motion

b. RAO Pitch Motion

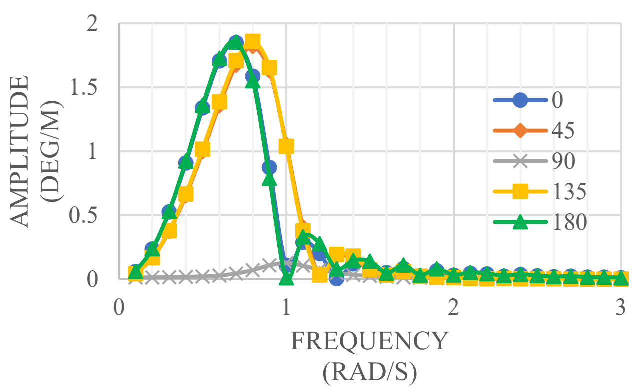

Figure 8. PLB Hafar Neptune RAO on Pitch Motion

f. RAO Yaw Motion

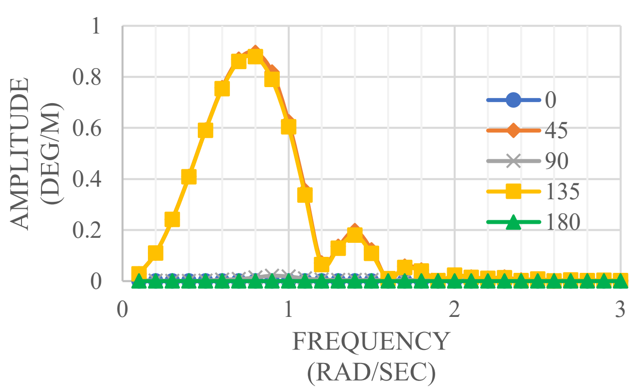

Figure 9. PLB Hafar Neptune RAO on Yaw Motion

g. Maximum RAO Value of PLB Hafar Neptune

Next, the maximum amplitude of each movement on RAO Hafar Neptune PLB will be explained on the following table:

Table 8. Maximum RAO Value of PLB Hafar Neptune

Motion	Maximum Amplitude	Frequency (rad/s)	Wave Direction
Surge	0.942 m/m	0.1	0
Sway	0.998 m/m	0.1	90
Heave	1.074 m/m	0.8	90
Roll	7.98 deg/m	0.9	90
Pitch	1.86 deg/m	0.8	135
Yaw	0.896 deg/m	0.8	45

3.5 Dynamic Analysis Results

Dynamic analysis for pipelaying activity is needed because pipe tension is also affected by vessel movement, current load, and wave load [13]. Dynamic analysis using OFFPIPE software requires multiple inputs. Namely RAO and wave spectrum. In this Final Project, the JONSWAP wave spectrum was used. The JONSWAP spectrum describes wind which results in waves with extreme sea state conditions. JONSWAP spectrum can be applied to waters by certain criteria [14]:

$$3.6 < Tp / (Hs)^{1/2} < 5 \quad (5)$$

For JONSWAP wave spectrum [15], can be seen on this following equation:

$$S(\omega) = a.g^2\, \omega^2 \exp[-1.25(\omega/\omega_p)^{-4}]\gamma^{exp[0.5(\frac{\omega-\omega p}{\sigma\omega})^2]} \quad (6)$$

Information:

a $= \frac{5}{16}\frac{Hs^2\omega p^4}{g^2}(1 - 0.287 ln\gamma)$

σ = *Spectral Width Parameter*

= 0.07 if $\omega \leq \omega_p$

= 0.09 if $\omega > \omega_p$

ωp = Angular Spectral Frequency (rad/s)

= 2π/Tp

ω = Wave Frequency (rad/s)

= 2π/T

Hs = Significant wave height (m)

Tp = Peak Periode (s)

T = Wave Periode (s)

Structural responses to random waves could be done by transforming the wave spectrum into the response spectrum. The response spectrum is defined as the energy density response to structures due to waves. This can be done by multiplying the square rank value of the Response Amplitude Operator (RAO) with the wave spectrum in the area where the floating structure operates [12]. Mathematical structure response equation can be written like Equation 7 below:

$$S_R = [RAO(\omega)]^2 \times S(\omega) \quad (7)$$

Information:

S_R = Response Spectra (m^2-sec)
$S(\omega)$ = Wave Spectrum (m^2-sec)
RAO(ω) = Transfer Function
ω = Wave Frequency (rad/sec)

OFFPIPE automatically calculated the height of the significant wave from the RAO and wave spectrum equation. The results were in von-misses stress or combination loads of the pipeline itself. The results of dynamic analysis are plotted in graphical form. There are 3 graphs of pipe diameter variations. On each graph, there are variations in the direction of the coming waves.

a. Dynamic Analysis on 8 Inch Pipeline

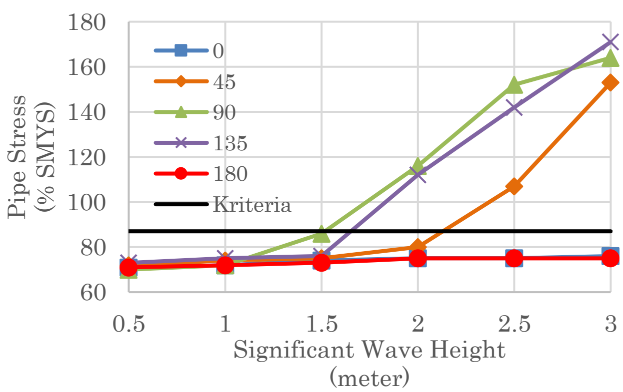

Figure 11. Pipe Tension Summary Chart on Dynamic Analysis of 8 Inch Pipeline

b. Dynamic Analysis on 10 Inch Pipeline

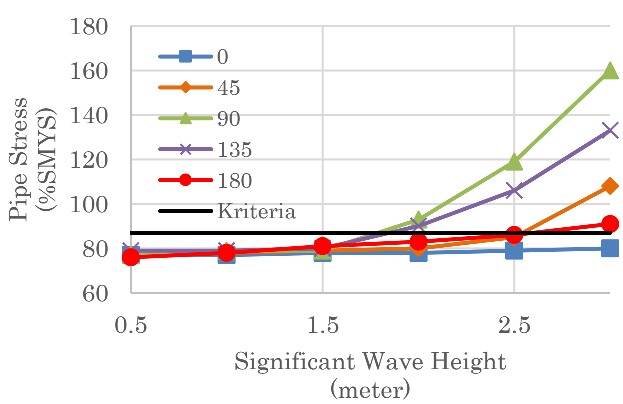

Figure 12. Pipe Tension Summary Chart on Dynamic Analysis of 10 Inch Pipeline

c. Dynamic Analysis on 12 Inch Pipeline

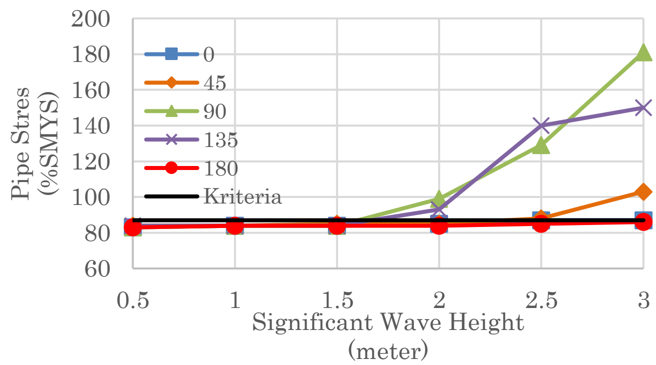

Figure 10. Pipe Tension Sumary Chart on Dynamic Analysis of 12 Inch Pipeline

4. CONCLUSION

From the analysis using some software, the following results are obtained:

a. Pipe Lay Barge Hafar Neptune could operate at the ONWJ region up to a significant wave height of 3 meters for all variations in pipe diameter

b. The maximum significant wave heights for each incoming wave direction were 3 meters for incoming wave direction 0°, 2.5 meters for incoming wave direction 45°, 1.5 meters for incoming wave direction 90°, 1.5 meters for incoming wave direction 135°, and 3 meters for incoming direction wave 180°.

5. ACKNOWLEDGEMENTS

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