International Journal of Offshore and Coastal Engineering
Vol.1 | No. 2 | pp. 56–63 | November 2017
e-ISSN: 2580-0914
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Submitted: July 17, 2017 | Revised: August 21, 2017 | Accepted: October 23, 2017

Analysis of Configuration of Stinger Angle with Depth Variation During Installation On Pipe Diamater 20" in Banyu Urip, Bojonegoro

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ABSTRACT

The selection of subsea pipeline construction methods used depends on the environmental conditions and behavior of the pipe installation system which acquires a variety of loads during installation and may the result in failure. In this case the required angle stinger configuration is in accordance with the criteria to avoid overstress and local buckling on the pipe during installation, the variation of the depth of 15 meters, 18 meters, 20.65 meters, 21.25 meters and 22.25 meters can help analysis the stress on the pipe in each case. The pipeline is 23.4 km north of Bojonegoro. From the results of the analysis, it is known that the configuration of stinger angles used during installation for each water depth is 15 m with stinger angle 8.88 degree, 18.65 m stinger angle 8.88 degree, 20.65 m stinger angle 8.88 degree, 21.25 m stinger angle 8.88 degree and 22.25 m stinger angle 8.88 degree. The result of pipe stress on the overbend area has a value of 85.13% SMYS or 352.42 Mpa when the direction of wave comes 90 degrees, while the sagbend area of the pipe has a maximum stress of 51.01% SMYS or 211.2 Mpa when the direction of wave comes 180 degrees. Local buckling check results in all conditions show safe results during the installation process.

Keywords: *stinger angle configuration, sagbend, overbend, local buckling*

1. INTRODUCTION

The development of the oil and gas industry is growing rapidly in Indonesia. The fastest growth of the oil and gas industry has encouraged increased consumption of oil and gas by the public. This requires the government to pay more attention to how to manage this industry especially in terms of distribution of oil and gas. An undersea pipeline development is one of the most effective measures in reducing operational costs during oil and gas distribution, compared to large oil and gas transportation using ship accommodation. Distribution by pipeline is relatively safe compared to bulk distribution [1]. A good level of security during installation will provide a profitable long-term investment in accordance with the specified operating life.

In this final project will be analysis stinger angle configuration at the Exxon Mobil pipeline project "Banyu Urip Project" in Bojonegoro Central Java Province. The project intends to install new pipelines in anticipation of increased production in the future. There are 3 phases of pipe that already exist and will be used as a gas pipe as well as a new pipe to transfer crude oil. In addition, this final project uses a 20 inch diameter pipe during laying process with S-Lay method with depth variation.

The analysis of this final project is done during the installation process to estimate minimum bending stress that occurs in the critical area to match the design criteria to avoid failure of the installation process. In this case the required angle stinger configuration is in accordance with the criteria to avoid overstress on the pipe during installation, the variation of depth can help the stress analysis on the pipe in each case.

In completing this study, it takes some data as parameter of the process. The data used in this final project between pipe parameter, pipe coating data, lay barge data, stinger data. After getting the data then the next step to verify the properties of the pipe that got in the field. Description of the pipe obtained with wall thickness of 0.5 inch and 20 inch diameter outside was available in the field. One example of the installation image of the pipeline S-Lay method as follows after this:

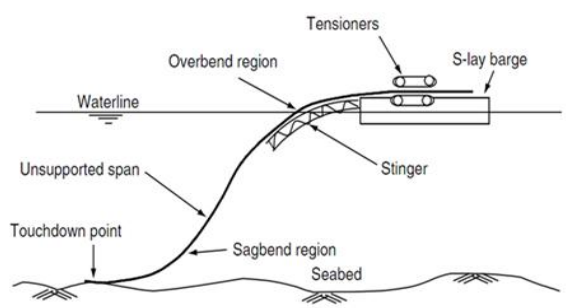

Figure 1.1 S-Lay Configuration [2]

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2. MATERIALS AND METHOD

The basic theories used in this final project study include the method of pipeline deployment, the process of pipeline deployment, code and standard used, the theory of forces that occur in the pipeline during the installation process.

2.1. Metode *S-Lay*

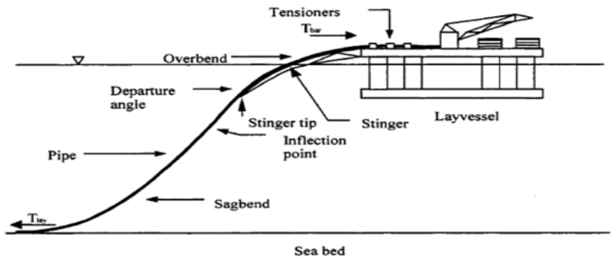

Figure 2.1 Installation S-Lay Method

Figure 2.1 above describes In a shallow depth area up to a depth of 600 meters the method for subsea pipeline installation is using the S-Lay method, called S-Lay due to the curve formed when the pipe reaches the seabed formed the letter "S".

In Lay-Barge there is usually a place for welding station (welding station), tension machine, NDT station to check welding and coating station. When the pipe is welded into several joints then proceeded to the process of entering the pipe into the sea, the process will help the pipeline into the sea due to the movement of the barge due to the mechanism of the anchor. Some rollers are placed on top of stinger and barge. This roller helps the pipe when the pipe moves from barge into the ocean

2.2. *Overbend*

The overbend area usually starts from the tensioner on the barge deck, through the barge ramp, and down to the stinger up to the lift-off point where the pipe is no longer supported by the stinger. In this overbend area the total stress expected from the weight of the pipe itself, the bending moment at the pedestal, or the roller does not exceed 85% SMYS, in other words the maximum bending stress experienced by pipes in the overbend area is less than 85% SMYS. The pipe bending strain equation is :

$$E = D/2R \quad (2.1)$$

where :

D = Outside diameter of pipe

R = Range of ring curvature from overbend area

While the equations for axial bending stress are :

$$\sigma = ED/2\sigma o DF \quad (2.2)$$

where:

F = Design factor (0.85)

$\sigma 0$ = SMYS (Specified Minimum Yield Stress)

2.3. *Sagbend*

The sagbend area usually starts from the inflection point until the touch down point on the seabed. The overbend voltage is controlled by stinger radius, depature angle and roller settings. Stress that occurs pipes in the sagbend area is expected to be less than 87% SMYS. The tension on the sagbend is expanded with the following parameters:

- Initial height
- Tension pipe at the starting point
- Overbend curve
- Pipe parameters

2.4. *Local Buckling*

Buckling is a condition where the pipe is not round or deformed due to large hydrostatic pressure at a certain depth. The possibility of buckling on a pipeline structure should be considered to avoid failure of the pipeline. Local buckling on the pipe is influenced by external pressure, axial force and bending moment. The buckling analysis according to DNV OS-F101 is done by analyzing the calculation of collapse and combined loading system. Calculation of collapse system is done to find the characteristic of collapse pressure (Pc). Pipes that are subjected to a combination of loads due to bending moments and axial forces during installation shall be checked for qualifications. Checking of the combined load working on the pipe is done for two conditions: Internal Overpressure and Extrenal Overpressure.

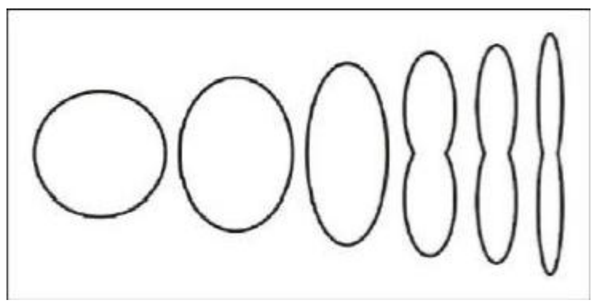

Figure 2.2 Ilustrastion of Local Buckling that Happen on Surface Area Pipe [3]

In Figure 2.2 above shows where the pipe occurs deformation bentu on the cross section of a pipe. The pipes experience this because there are some burdens that occur from the outside and inside. In addition, the pipe will also experience exsternal pressure, axial force, and bending moment during the installation process.

2.5. Standart dan Code

DNV OSF-101 is a practical guide and guidance for the property of subsea pipeline installation processes issued by a trusted independent agency [4]. DNV OS-F101 regulates material selection procedures, fabrication, installation, inspection, testing, commissioning, operation, maintenance, re-qualification and abandonment.

The format used in DNV OS-F101 uses LRFD (Load and Resistance Factor Design) and ASD (Allowable Stress Design). During the installation process and operation of the offshore pipeline system accepting fluctuating loading either from environmental load, incident load or installation load. Under actual conditions, the load uncertainty is anticipated by multiplying certain factors for the load occurring.

3. METHOD

In order to facilitate the preparation of the final project in a sequential and systematic process work can be seen in the diagram below :

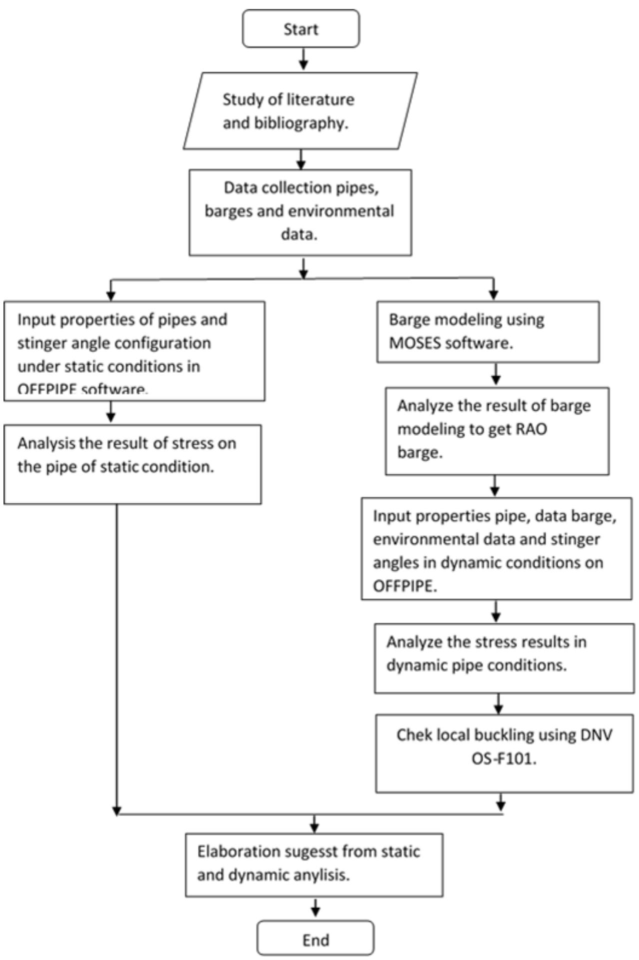

Figure 3.1 Flowchart diagram

In this final project will be described each sequence of work steps that have been prepared in the form of flowchart diagram on the previous page. The steps undertaken in this final project are as follows:

1. Literature Studies and Review
he literature study conducted in this case aims to establish theoretical basis, it is related to the literature and journals both from within and outside the country related to the discussion of the material studied in this study. The books, journals and data are used as guidance in conducting this Final Project study related to pipeline analysis during installation by the S-Lay method. And learn the software that will be used is OFFPIPE software.

2. Collect Data
The field study was conducted to find the necessary data on the discussion of problems to be analyzed in this study. Field study can be done by direct observation of the object to be studied or just by looking at some related data or in accordance with the problem to be studied or looking for some data as preparation activities for the implementation of this study. The data to be used starts from pipe design data, environmental data and parameter coatings is a project of Exxon Mobil Field Banyu Urip Project in Bojonegoro, Central Java Province. The required data are pipeline diameter, pipeline thickness, weight and pipeline material type.

3. Input Properties Pipa And Configuration of Stinger Angel
Under static conditions in OFFPIPE software. At this stage we enter the stinger configuration that has been varied in every depth.

4. Analisa Stress of Pipa During Static Condition
At this stage analyzes the results of running offpipe software with pipe data input in the barge silent (static).

5. Modeling of Pipe Lay Barge
Creating a Hacking Neptune barge modeling on MOSES software based on the data that has been obtained. This modeling is when the barge is in free floating condition.

6. Anylisis Barge Modeling to Receive RAO Barge
Validation of barge is done by comparing the result of barge modeling between software MOSES and data barge that exist in the field. If the validation is not met, then the modeling barge must be done again with MOSES software until it satisfies the validation requirements. Based on IACS, the validation criterion on displacement is 2%. This analysis is also to obtain the characteristic of ship motion in every direction of the coming wave.

7. Input Properties Pipe, Dimension Barge, Data Environmental and Configuration Angle of Curvature
Under dynamic conditions in OFFPIPE software. At this stage we include the stinger configuration that has been set to be used for dynamic condition analysis in each depth before.

8. Analysis Stress of Pipe during Dynamic Condition
The analysis is done by looking at the result of OFFPIPE running software which has input variation of angle stinger configuration with variation of depth, stress analysis that happened on pipeline based on DNV OS F-101 where voltage should not exceed 87%.

9. Calculation od Buckling
Local buckling analysis refers to DNV OS F101. This local buckling is derived from a critical combination of bending moment and axial force which u s then sought, the result must be less than 1.
10. Suggest and Conclusion
Arrange the conclusions in accordance with the issues raised as well as the expected goals.

4. ANALYSIS AND DISCUSSION

4.1 Collecting and Indetification of Data

The data used in this research analysis is the data of an Exxon Mobil project under the name of the project "Banyu Urip Project" located in Bojonegoro province of Central Java. The location of the project is located at 23 km near the northsea waters of Tuban. Pipe installation is used S-Lay method

Tabel 4.1 Water Depth

Case	Depth (m)
Case 1	15
Case 2	18.65
Case 3	20.65
Case 4	21.25
Case 5	22.25

Tabel 4.2 Strom Tide

Item	value	Period	
		1 – year	100 - year
Strom Tide (Surge)	m	0.152	0.244
Higest Astronomical Tide (HAT)	m	1.158	1.158

Tabel 4.3 Wave Parameter

Period	Signifikan Wave	Max Signifikan Wave	Wave Period
	(m)	(m)	(seconds)
1 – year	1.2	3.7	6.531
5 – year	1.3	3.8	7.326
10 - year	1.7	4	7.974
100 – year	2.4	4.8	9.873

Tabel 4.4 Data of Current

Velocity of Current	1	5	10	100 y
At 0% of depth (m/s)	0.71	0.72	0.79	1.24
At 20% of depth (m/s)	0.67	0.67	0.68	0.69
At 50% of depth (m/s)	0.64	0.64	0.65	0.65
At 70% of depth (m/s)	0.59	0.59	0.59	0.59
At 90% of depth (m/s)	0.42	0.42	0.42	0.42
At 100% of depth (m/s)	0.24	0.24	0.24	0.24

Tabel 4.5 Soil Parameter

Parameter	Units	Value
Soil type	-	Very soft clay
Undrained shear strength	kPa	2 - 6
Angle friction	Deg	0
Submerged weight	Kg/m^3	815.7

Tabel 4.6 Sea Water of Property

Parameter	Units	Value
Density of sea water	k/m^3	1025
Sea water temparature	^0C	26.67
Kinematics viscosity	m^2/s	1.13×10^{-5}

Tabel 4.7 Pipe Data

Description	Unit	Value
Outside Diameter	mm (inch)	508 (20)
Wall Thickness	mm	12.7
Internal Corrosion Allowance	mm	1.6
Material Grade	-	API5L Gr.X60 PSL2
Linepipe Material		LSAW and ERW
SMYS	MPa	414
Linear Cooefficient of Thermal Expansion	m/m^0C	1.18×10^{-5}
Modulus of Elasticity	MPa	2.07×10^5
Poisson's Ratio	-	0.3
Density of Steel Pipe	kg/m^3	7850

Tabel 4.8 Data *Coating* of Pipe

Description		**Unit**	**Value**
Anti-Corrosion Coating	*Material*	-	FBE (Fusion Bonded Epoxy)
	Thickness	mm	0.61
	Density	kg/m^3	1000

Concreate Coating	*Density*	kg/m^3	3040
	Cut - Back	mm	266

Tabel 4.9 Data of *Lay Barge*

Description	**Barge Parameter**
Maximum Pipe Tension Avaible (sum of 2 tensioners)	60 MT
No. Of Tensioners Avaiable on the Barge	2 nos
No. Of Rollers on the Barge	7 nos
Length of Tensioner	6.5 m
Hitch X-Location (w.r.t stern)	0.497 m
Hitch Y-Location (w.r.t main deck)	-1.80 m
Barge Moulded Dimensions	Length = 85 m
	Breadth = 25 m
	Depth = 5.5 m

Tabel 4.10 Data of *Stinger*

Description	**Value**	**Units**
No.of Rollers on Stinger	5	nos
Stinger Length	42	m
Stinger Roller Bed Length	2.586	m
Increment Rotation Angle (from horizontal)	2.22	deg

Tabel 4.11 *Configuration Roller Support on the Barge*

Description	**Coordinate**		**Location**
	x (1)	**y (2)**	
R1	64.218	1.838	*Deck*
R2	59.738	1.76	*Deck*
R3	48.239	1.56	*Deck*
T1	38.191	1.384	*Ramp*
R4	33.473	1.302	*Ramp*
T2	26.705	1.184	*Ramp*
R5	21.441	1.092	*Ramp*
R6	12.225	0.799	*Ramp*
R7	0.055	-0.227	*Ramp*

Where:
R = *Roller*
T = *Tensioner*
1 = *Form strem forward* (+)
2 = *From deck upward* (+)

Table 4.12 *Configuration Roller Support on the Stinger*

Description	**Coordinate**	
	x (1)	**y (2)**
S1	-8.325	1.694
S2	-16.324	1.994
S3	-24.324	1.944
S4	-31.698	1.544
S5	-37.948	0.944

Where :
1 = *From hitch point forward (+)*
2 = *From stinger upward (+)*
S = *Stinger*

Tabel 4.13 *Loadcase* with Variation Water Depth Depth and Configuration Angle of Stinger

STATIC CASE	Water Depth (m)	Stinger Angle (deg)	Outiside Diameter (inch)	Wall Thickness (cm)
CASE 1	15	4.44	20	5
		5.55		
		6.66		
		7.77		
		8.88		
CASE 2	18.65	4.44	20	5
		5.55		
		6.66		
		7.77		
		8.88		
CASE 3	20.65	4.44	20	5
		5.55		
		6.66		
		7.77		
		8.88		
CASE 4	21.25	4.44	20	5
		5.55		
		6.66		
		7.77		
		8.88		
CASE 5	22.25	4.44	20	5
		5.55		
		6.66		
		7.77		
		8.88		

For this analysis will be used 5 cases as in the table before where at each depth of the sea will be varied stinger angle. From the case above that obtained the results of running as follows:

Tabel 4.14 The Result of Static Condition

			SAGBEND MAX		OVERBEND MAX	
CASE	DEPTH	ANGLE STINGER	TOTAL YIELD	PERCENT YIELD	TOTAL YIELD	PERCENT YIELD
	m	deg	MPa	%	MPa	%
1	15	4,44	151,3	34,26	316,9	76,55
		5,55	151,55	36,61	298,83	72,18
		6,66	151,31	36,42	259,08	62,58
		7,77	150,78	36,42	227,82	55,03
		8,88	149,85	36,2	288,95	**69,8**
2	18,65	4,44	158,29	38,23	315,41	76,19
		5,55	158,59	38,31	335,61	81,06
		6,66	157,9	38,14	321,92	77,76
		7,77	157,5	38,04	282,22	68,17
		8,88	157,95	38,15	266,23	**64,31**
3	20,65	4,44	160,74	38,83	310,44	74,99
		5,55	161,38	38,98	335,08	80,94
		6,66	161,97	39,12	352,64	85,18
		7,77	161,51	39,01	314,5	75,97
		8,88	160,84	38,85	275,09	**66,45**
4	21,25	4,44	162,03	39,14	309,02	74,64
		5,55	161,96	39,12	333,59	80,58
		6,66	162,85	39,33	351,88	84,99
		7,77	162,63	39,28	323,82	78,22
		8,88	160,650	38,810	284,630	**68,75**
5	22,25	4,44	163,89	39,59	306,69	74,08
		5,55	163,13	39,4	331,18	80
		6,66	163,94	39,6	351,49	84,9
		7,77	160,19	38,69	339,03	81,89
		8,88	163,99	39,61	300,18	**72,51**

4.2 Modeling Barge

Modeling is done by referring to general arrangement (GA) data and other data required. After obtaining the appropriate model, the model is transferred to MOSES by decrypting the coordinate points for further analysis. Modeling with the dimesni data of the ship as follows:

Tabel 4.15 Data Dimensi *Barge Hafar Neptune*

LOA	85.344 m
Breath	24.384 m
Depth	5.4864 m
Draft	2.5 m
Trim	0.5 deg

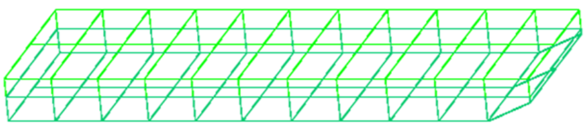

Figure 4.1 Model Geometry of *Barge* View Isometry

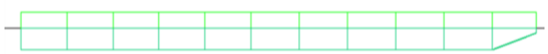

Figure 4.2 Model Geometry of *Barge* View Side

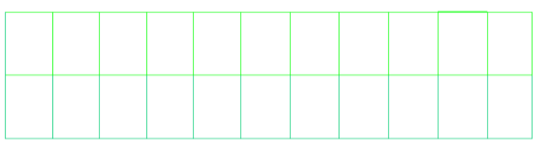

Figure 4.3 Model Geometry of *Barge* View Surface

Figure 4.4 Model Geometry of *Barge* View *Bow*

With modeling above that we get the result of response analysis of amplitude barge in certain direction. Then we get dynamic analysis results as follows:

Tabel 4.16 The Result of Anylisis Dynamic

Cases	Depth	Stinger Angle	Heading	Stress (%)	
	(m)	deg	deg	Over bend	Sagbend
1	15	8.88	0°	59,23	36,91
			45°	63,58	39,05
			90°	71,49	42,72
			180°	68,53	42,99
2	18,65	8,88	0°	66,33	38,45
			45°	68,65	38,16
			90°	72,02	42,46
			180°	69,59	43,11
3	20,65	8,88	0°	65,53	39,01
			45°	70,73	41,46
			90°	73,4	42,34
			180°	70,31	42,63
4	21,25	8,88	0°	67,25	39,38
			45°	72,14	41,87
			90°	75,2	43,18
			180°	82,28	47,51
5	22,25	8,88	0°	68,76	38,81
			45°	77,78	46,81
			90°	85,13	48,86
			180°	85,04	51,01

4.3 Calculation of Local Buckling

After getting the result of pipe installation modeling using Offpipe software, it is obtained the maximum bending moment and maximum axial force which then becomes the input to perform buckling analysis. Local Buckling is influenced by external pressure, axial pressure and bending moment which then permissible combination for overbend and sagbend area. Local Buckling is a critical combination of longitudinal and hoop stress. In this final project research the standard reference used to check the pipeline local buckling is DNV OS F-101. From the above results we can say that the pipeline is safe from the existence of local buckling because permissible combination of all dynamic case is not more than 1. it can be said pipe on the overbend area all meet and safe. Here are the steps of working on the above equation:

1. Safety class resistance factor or γsc according to table 5-3 on DNV OS F-101 we determine the high for safer installation conditions worth 1.26.
2. Material strength factor or αU value 1 according to table 5-4 on DNV OS F-101 while material resistance factor or γM is value 1 because we adjust to the limit states we choose. While the resistance factor or γM is 1 because we match the limit states we choose. While the αFab or fabrication factor we set is 0.93 according to the type of pipe to be installed and the condition load effect or γc in select value 1 because the pipeline is assumed to lie on the flat seabed. For load effect factor combintaion succession we choose γFa 1.2, γFb 1.1, γEa 0.7, γEb 1.3.

3. The next step is to calculate the external pressure which is formulated in the following equation :
   $\rho e = \rho water\ x\ depth\ x\ g$ (4.2)
4. Calculate the pressure containment resistance given equation formula as follows :

   $$\rho b\ (t) = \frac{2\ x\ t}{D-t}\ x\ fcb\ x(\frac{2}{\sqrt{3}}) \quad (4.3)$$

5. Calculate the collapse system in symbolized by Pc which has the equation formula as follows :
   Pc = y – 1/3 b (4.4)
   Factors used to calculate the collapse system have been given completely in DNV OS F-101 section 13 commentary chapter D 700 part local buckling - collapse.
6. The last of the maximum axial tension and bending moment that have been obtained previously changed to design load effect or Msd and Ssd to meet the local buckling check equation above which is given the following equation :
   Msd = Mf . γf. γc + Me . γe + Mi . γf . γc + Ma . γa . γc (4.5)
   Msd = Sf . γf. γc + Se . γe + Si . γf . γc + Sa . γa . γc (4.6)

5. CONCLUSION AND SUGGESTION

5.1 Conclusion

1. In moving barge conditions (dynamic) the maximum stress of the pipe in the overbend area has a value of 85.13% SMYS or 352.42 Mpa when the direction comes 90 degrees, while the sagbend area of the pipe has a maximum stress of 51.01% SMYS or 211.2 Mpa When the direction comes 180 degrees. Local buckling check results in all conditions show safe results during the installation process.
2. Configuration angle used in the analysis during the installation process so as not to occur excessive stress on the pipe for any depth of 15 m with stinger angle 8.88^0, 18.65 m angle stinger 8.88^0, 20.65 m angle stinger 8.88^0, 21.25 m angle stinger 8.88^0 and 22.25 m angle Stinger $8{,}88^0$.

5.2 Suggestion

1. For dynamic analysis checking safe criteria based on design load is only done on some headings. In the next research is expected to be able to analysis all the headings that have not been discussed in this project.
2. Important to calculation and modeling the stinger in MOSES software to get more detailed laybarge motions.

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