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Analysis of Thickness and Stability of Subsea Pipes in Masela Block Work Area, Yamdena Island

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Abstract

Submarine pipeline is a transportation or concept used to transport hydrocarbon products such as crude oil and high-pressure natural gas. The fluid material or gas is pumped from the platform across the seabed using a pipeline. The Abadi Field in the Masela Block is one of the National Strategic Projects (PSN) located in the Tanimbar Islands Regency, Maluku Province. The block was developed by INPEX Masela Ltd. It geographically borders to Timor Leste and Australia. It was discovered in 2000 and contains potential gas reserves which reaching 10.73 trillion cubic feet (Tcf). This research aims to determine the minimum thickness of submarine pipelines, determine on-bottom stability in accordance with DNV RP-F109, and visualize the maximum pressure caused by significant current flow on the pipe surface by using Ansys Computational Fluid Dynamics 2023 R2 Student Version. This research method is used a quantitative. The analysis result of this research that have been obtained, the thickness of the pipe is 11.2 mm. The calculated of on-bottom stability is 0.012 for vertical and 0.008 for lateral stability. In Additionally, by using Ansys Computational Fluid Dynamics 2023 R2 Student Version, maximum pressure of the pipe is 14 Pa.

Keywords: Pipeline, Stability, Wall Thickness

1. INTRODUCTION

The Abadi Field in the Masela Working Area or abbreviated as the Masela Block is one of the National Strategic Projects (PSN) located in the Tanimbar Islands, Maluku. This area is one of the largest oil and gas fields in Indonesia. This area geographically borders Timor Leste and Australia. This work area was developed by the company INPEX Masela Ltd.

This area is the largest oil and gas field in Indonesia. This block geographically borders Timor Leste and Australia. This reserve was first discovered in 2000 and has huge potential gas reserves reaching 10.73 trillion cubic feet (Tcf). This project is carried out in a zone of 4,291.35 km2 in the Arafura Sea and around 800 km on the east side of Kupang City , East Nusa Tenggara Province.

Until now, the project is still in the development stage. This development certainly involves engineers designing an underwater pipeline. Especially in the design or modeling of underwater pipe construction, it is very necessary as a medium for engineers and owners to avoid failure during operation, hydrotesting. Especially in the design or modeling of pipeline construction, it is very necessary as a communication medium for engineers and owners to avoid failure conditions during operations, hydrotests or in the construction of underwater pipeline work.

In addition there is codes in planning pipeline like The Norwegian Veritas (DNV), American Petroleum Institute (API) and others. In planning submarine pipelines should determine the thickness of the pipe based on pressure containment, external pressure, buckle propagation and on-bottom stability.

2. LITERATURE REVIEW

A submarine pipeline or submarine pipeline is a transportation tool or concept used to anchor hydrocarbon products such as crude oil and high-pressure natural gas. A very important aspect in subsea pipeline design is the selection of pipe material, pipe thickness and stability. Pipe materials are selected based on design aspects such as internal pressure, external pressure, and pipe diameters that comply with certain codes.
In determining the diameter of the pipe, the criteria that must be observed are: pressure containment or internal pressure and external pressure on the pipe. So there are regulations that regulate pipe thickness and pipe stability, such as DNV (Det Norske Veritas), ASME (American Society of Mechanical Engineering) and APIs (American Petroleum Institute).
The planned pipe thickness design is regulated in the ASME B31.8 standard regarding Gas Transmission and Distribution Piping System. From the ASME B31.8 standard, the equation regarding finding pipe thickness is presented in the equation:

$$t = \frac{Pd_0}{2FETS_y} \quad (1)$$

This equation is used so that the results of this equation can meet the thickness of the pipe based on internal pressure to withstand pressure in the tangential direction. In pipes that are submerged at the underwater surface, of course the pipe will experience hydrostatic pressure. Hydrostatic pressure is the liquid pressure experienced by an object. In determining the design hydrostatic pressure value, this equation is described as follows:

$$Ph = \rho gh \quad (2)$$

From the hydrostatic pressure obtained, the value can be determined Collapse Due to External Pressure which is a failure in the pipe caused by external pressure. External pressure can be thought of as hydrostatic pressure. So the equation on collapse due to external pressure is :

$$Py = 2S\left(\frac{t}{D}\right) \quad (3)$$

$$Pe = 2E\left(\frac{t}{D}\right)^3 \quad (4)$$

$$Pc = \frac{Py+Pe}{\sqrt{Py^2+Pe^2}} \quad (5)$$

In offshore structures, the deeper the pipe location, the greater the external pressure acting on the pipe. So, it can happen collapse on the pipe itself. After calculating collapse due to external pressure, Next is to calculate buckling due to combined bending which is given the following equation:

$$Pbp = 24\ S\ F_t\left(\frac{tbuck}{OD}\right)^{2.4} \quad (6)$$

After getting the propagation buckling pressure value, then determine the minimum pipe thickness value using the equation:

$$t_{req} = t_{min} + + t_{fab} \quad (7)$$

Seabed stability is a very important factor in designing pipelines. Pipelines that stretch across the seabed will withstand fluid pressure from both currents and waves. Analysis of seabed stability is referred to as on-bottom stability. There are also two types of stability, namely vertical stability and lateral stability.
The regulation related to the stability of subsea pipelines is DNV RP-109 On-Bottom Stability Design of Submarine Pipelines. Pipes under the sea are generally composed of layers that have different types of forming materials and thicknesses, for example thick wall layers, anti-corrosion layers and anti-corrosion layers concrete.
So that pipeline can be vertically stable on the surface of the seabed, the following equations must be met according to DNV RP-109

$$\gamma_w \frac{b}{w_s b} = \frac{\gamma_w}{s_g} \leq \mathbf{1.00} \quad (8)$$

In analyzing lateral stability, there are 3 methods used. According to DNV RP 109 On-Bottom Stability Design of Submarine Pipelines, here are the 3 methods:

1. Method Dynamic Lateral Stability
2. Method Generalized Lateral Stability
3. Method Absolute Lateral Stability

In the case of the absolute lateral stability method, this method fulfills the following equation:

$$\gamma_{sc} = \frac{F_{\gamma B} + \mu . F_{ZB}}{\mu . W_s(t_{cc}) + F_R} \leq \mathbf{1.00} \quad (9)$$

3. RESEARCH METHODS

3.1 Research Location

This research was carried out at the Research Laboratory for Production Management of Offshore Buildings and Underwater Work, Department of Marine Engineering, Faculty of Engineering, Hasanuddin University, Gowa.

3.2 Types of Research

This research is quantitative research, by collecting data, managing data and displaying valid results so that results are expected from the given hypothesis.

3.3 Research Methods

The research method used in this research is quantitative. Namely using numbers, starting from collecting data, interpreting the data and displaying the results of this research and literature study by studying and collecting literature that is relevant to this research.

3.4 Research Procedures

The procedure of this research is explained in the following steps:

1. Data collection.
   In this research we will look for current data, wave data, layout bathymetry and pipe dimensions in the Yamdena Island area and the Masela Block Working Area.
2. Determination of Pipe Thickness
   In determining pipe thickness, the first step is to calculate pressure containment, hydrostatic pressure, propagation buckling, collapse due to external pressure, and buckling due to combination bending.
3. Stability analysis or on-bottom stability
   After determining the thickness of the pipe, next calculate on-bottom stability. In the case of lateral stability, the method used is absolute lateral stability
4. Maximum pressure visualization
   Pressure caused by significant current flow on the pipe surface in the form of a simulation using Ansys software Computational Fluid Dynamics Q2 2023 Student Version.

4. RESULT AND DISCUSSION

In this research, the data used are bathymetric layout, currents, waves and pipe materials. The pipe diameter obtained in previous research was 24 inches. Bathymetry data is used to provide an overview of the topography and depth of the seabed. Figure 9 shows the seabed elevation at the Yamdena Island location and its surroundings showing seabed elevations from -100 m to -1500 m. The bathymetry data in this study is secondary data so the data was taken from GEBCO and processed using Global Mapper and ArcGIS Map software.

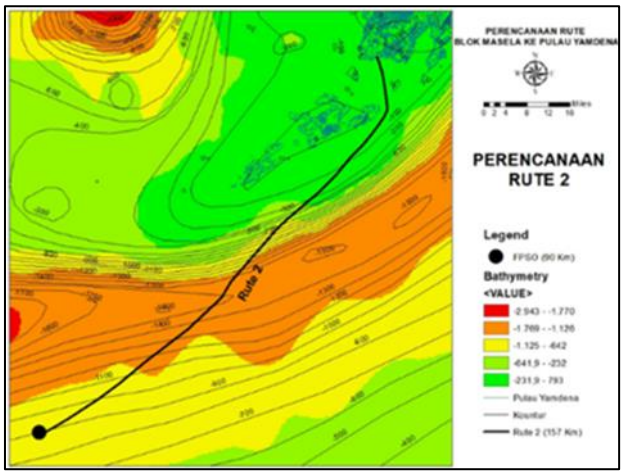

Figure 1. Layout Bathimetri [Hasil Analisis, 2024]

Based on Figure 1, Yamdena Island is an island in the Masela Block Working Area and is the largest island that borders Australia and is separated by the Arafuru Sea. The location of the FPSO in question is at coordinates 130°41'37.91"E East Longitude and 9°18'56.60"S South Latitude. Regarding natural resources, the area that will be drained by underwater pipes is the Hydrocarbon type. This gas can be liquefied. So, the material is determined based on the strength of the pipe to be used, the parameters of the operation and design and the type of fluid being carried. Based on data from previous research, the planning uses a pipe diameter of 24 inches with material Alloy Steel. The following is Table 1 data on the properties of the pipe material to be planned.

Table 1. Pipe Material Data

Parameter	Unit	Value
Size	Inch	24
Internal Pressure	MPa	6.5
Diameter	Inch	24
Density of Steel	kg/m^3	7850
SMYS	MPa	290
Poisson Ratio		0,3

Material use Alloy Steel very efficient and suitable for subsea pipelines. The efficiency of using alloy steel material is that this material is anti-corroting coating. This material is very suitable because the salinity of sea water can cause objects to corrode.

In designing or determining pipe thickness, the pipe thickness must be able to withstand internal pressure and external pressure on the pipe. The external pressure of the pipe can be assumed to be hydrostatic pressure. From hydrostatic pressure, the large hydrostatic force on the pipe can cause the pipe to collapse. So the magnitude of the hydrostatic force is presented in Table 2 below.

Table 2. Hydrostatic Pressure

Hydrostatic Pressure	Unit
$1.005 \cdot 10^6$	Pa

Factors that influence hydrostatic pressure are gravitational acceleration, liquid density and depth of the liquid. Because hydrostatic pressure depends on the depth of the liquid, it causes the liquid to press on an area of pressure at a certain depth. The depth value is taken using the largest depth.

In offshore structures, the deeper the planned pipeline, the greater the external pressure or hydrostatic pressure. From the difference in these values, the external pressure that works can cause the pipe to collapse. So from hydrostatic pressure, the pipe can experience propagation in the pipe. This definition is a condition where the pipe experiences deformation in the cross-sectional shape of the pipe or other pipe components. Based on the forces acting on the pipe at sea depths, it is necessary to design a pipe thickness that can withstand these forces. So Table 3 below is the appropriate pipe thickness to use.

Table 3. Pipe Thickness Values

Formula Input	Unit	Nominal Thickness
Pressure Containment	mm	7,2
Collapse Pressure	mm	1,5
Propagation Buckling	mm	1,68
Combination Bending	mm	2,5

From the values that have been obtained, the largest nominal value is taken in determining the pipe thickness. In determining, there are variables including mill tolerance, minimum wall thickness and corrosion allowance. After the values for pressure containment, propagation buckling and collapse pressure have been obtained, the next step is to determine the minimum pipe thickness. Table 4 below is the minimum thickness required.

Table 4. Minimum Pipe Thickness

Formula Input	Unit	Nominal Thickness
Minimum Wall Thickness	mm	11,2

The variables taken are the largest variables. Table 4 shows that value pressure containment is the greatest value. The value is added to the value mill tolerance, corrosion allowance and value construction allowance. To determine the mill tolerance, namely 15% of the largest variable. The corrosion allowance value is determined according to the fluid flow carried by the pipe. Pipes fed by hydrocarbons use corrosion allowance, up to DNV OS F101, value corrosion allowance recommended value of 3 mm.
The stability of pipes installed on the seabed is greatly influenced by the gravity acting on the pipe. So to analyze pipe stability, it is done in two ways, namely vertical stability and lateral stability. The procedure used to calculate stability in this journal uses the DNV RP-F109 standard On-Bottom Stability Design of Submarine Pipeline. The following is Table 5 which presents the values for lateral stability and vertical stability.

Table 5. Vertical and Lateral Stability

Formula Input	Unit	Nominal
Vertical Stability	-	0,012
Lateral Stability	-	0,08

In vertical stability, hydrodynamic or environmental forces on the underwater pipe have no effect on the object. However, the hydrostatic pressure acting on the pipe has a great influence on the pipe. So that the pipe can be optimally stable, ballast is used with a concrete blanket with a thickness of 12.4 mm with an anti-rust thickness of 3 mm.
The method used to calculate lateral stability according to DNV RP F109 “On-Bottom Stability Design of Submarine Pipelines” is to use a method Absolute Lateral Static Stability Method. So this method is a static balance of forces that determine the pipe's resistance to movement to withstand maximum hydrodynamic loads. In determining lateral stability, there is a safety factor value which is determined according to environmental conditions. Based on related references, there are two conditions, namely cyclonic and winter. Cyclonic is defined as a condition where the waters of an area tend to experience storms. Meanwhile, winter is a condition where storms are rare.
Subsea pipeline modeling using Ansys Computational Fluid Dynamics 2023 R2 Student Version. This model was designed by inputting a significant flow velocity variable in the bottom pipe of 0.14 m/s with a pipe length of 12 m with a diameter of 0.609 m or 24 inches.

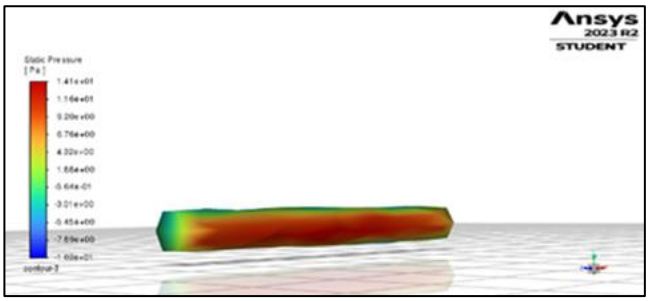

Figure 2. Pipe Pressure Contour [Analysis Results, 2024]

In Figure 2 above, the red contour indicates that the solid wall (pipe) is experiencing pressure caused by the arrival of a significant current flow (inlet). The inlet in this model is the direction of significant flow velocity with a speed of 0.14 m/s which is on the X axis. The current flowing through the pipe experiences streamlined flow. Figure 3 below shows the streamline flow around the pipe.

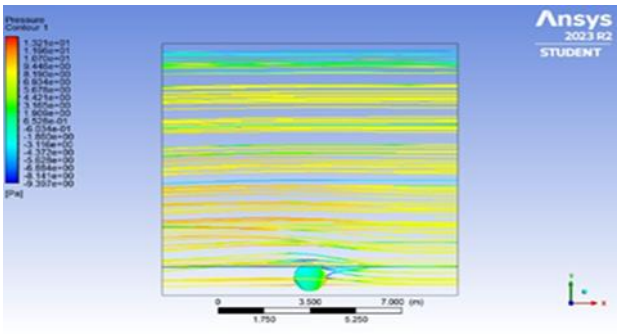

Figure 3. Flow Streamline [Analysis Results, 2024]

The streamline flow visualized in Figure 3 is a current flow that hits the pipe perpendicularly. The pipe surface that is directly exposed to significant current flow experiences a maximum pressure of 14 Pa. This value is the limit value to say that the pipe is categorized as safe to operate. So if the pipe experiences a value exceeding 14 Pa, the pipe will experience turbulence caused by significant current flow hitting the surface of the pipe. In addition, exceeding this value can cause deformation caused by the pressure of the current flow.

5. CONCLUSION

Based on the results of the analysis, the following conclusions were obtained:

1. The pipe thickness obtained is 11.2 mm
2. The vertical stability obtained is 0.012 and the lateral stability is 0.008, where the pipe is in a condition where it has been installed thickly. concrete coating and corrosion coating. So it is based on DNV RP-F109 regulations On-Bottom Stability Design of Submarine Pipelines less than 1.1 so that from manual calculations it meets
3. Visualization using software Ansys Computation Fluid Dynamics 2023 R2 Student Version which is caused by a significant current flow velocity, a maximum pressure value of 14 Pa is obtained.

For the sake of developing the theme of this research, the following suggestions are concluded:

1. Need to add calculations On-Bottom Rougness, VIV (Vortex-induced Vibration) and Stress Analysis so that the analysis of underwater pipes can be more accurate
2. It is necessary to add other methods to determine lateral stability such as Dynamic Lateral Stability and Generalized Lateral Stability
3. A more precise installation process using simulation software Orca Flex.

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