Risk Assessment of Subsea Pipeline of Natural Gas in The Cross Area: Case Study in West Java Waters

Z Ariany1,2, B Santoso3 and Suharto2

1Departement of Marine Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia
2Department of Industry, Nautical Design and Construction Technology, Vocational School, Universitas Diponegoro, Semarang, Indonesia
3Department of Naval Architecture Engineering Polytechnic of Bengkalis, Riau, Indonesia

E-mail: zariany0409@gmail.com

Abstract. The Risk assessment for 20 inches’ pipeline of the Natural Gas from the Floating Storage Regasification Unit (FSRU) to the landing point which has long about 14 km is made due to the crossing pipes between existing and incoming pipe which has effect to ship activity of the Patimban Port and Operations Office (KSOP) working area. The depth of water in the assessed pipeline varies in the range of 0-16 m, from the outermost coastline 14 km to the FSRU. After the subsea pipeline installation, the area becomes a restricted/restricted zone so that only ships from existing and incoming who can operate in the area. The risk assessment of this gas pipeline is based on the assumption of the worst-case by ships operating around the pipeline. Assumed also that ships with the largest and heaviest anchors in each group of ships will drop and pull anchors so there is a risk of the existence of this gas pipeline. In the area of pipe crossing, the risk assessment will be carried out on the stability of the pipe stretch and land subsidence. The risk assessment methodology on this gas pipeline is carried out using Det Norske Veritas – recommended practice - F107 risk assessment of pipeline (DNV-RP-F107) as a reference. The frequency and consequences of several conditions and groups of ships are analyzed which will produce the level of risk, presented in the form of a risk assessment matrix to describe three risks as dropped anchor, dragged anchor and sinking ships also possibility impact of the damage. The results of the risk assessment become a reference for mitigation making and recommendations needed to improve the level of risk and impact of each case, therefore it can be ensured for all conditions do not have values that endanger the pipeline.

1. Introduction
Risk Assessment was prepared to assess the potential risk of existence pipeline 20-inch natural gas from the FSRU to incoming pipe around 14 km length in Karawang waters, West Java. The subsea pipeline is to deliver natural gas from the FSRU to Gas & Steam Power Plant as its fuelled. The purpose of the construction of the Java-1 PLTGU Project is to ensure the availability of sufficient
electricity supply to anticipate the growth of electricity consumption which grows by an average of 2,329 MW per year for the Java, Madura and Bali area. At the time of the analysis of the frequency and consequence, analyses a highscores, hence it need for mitigation. This condition allows for the occurrence of high accidents [1]. Their load such as external dropped anchors, dragged anchors, sinking ships and other dropped objects which occur the pipeline damage [5]. The design of subsea gas pipeline with a concrete layer will reduce the risk of dropped ships anchor [6]. The offshore pipeline is located in waters which cause problems if there is a trestle construction [9].

2. Methodology
The procedure for risk assessment for submarine power lines is as follows the document inspection to determine the initial design of a structure. Examinations include design, project location maps, shipping lines, vessel data on shipping lines and submarine contours. Reference can be in the form of standards that apply for national and international which includes references in material, construction design, inspection and maintenance. Risk is the probability of an event causing a loss. Mathematically risk assessment is expressed by the frequency relationship multiplied by the consequences [8]. Analysis in the form of model calculations, have been made from some data that has been collected in the form of documents, drawings, and references to a visual inspection. The data that has been obtained then analyzed according to the likely magnitude of the impact that occurs, and the frequency that occurs refers to government regulations, shipping, and other related standards/codes. The results of the frequency and impact are then grouped against the path that passes through the crossing pipe and does not cross the crossing. Furthermore, the analysis of the depth of the pipe immersion obtained the size of ships and anchors that have potential risks to the pipeline. This risk assessment uses a risk assessment analysis based on DNV-RP-F107 with simplification in 2 cases of risk, namely dropped anchor, and dragged anchor as shown in the diagram below [2]:

![Risk Analysis Diagram](image)

**Figure 1. Risk Analysis Diagram [2]**

2.1. Dropped Anchor Energy Analysis
The dropped object will be used to determine the technical and operational protection requirements to reduce the risk of damage to the pipeline path [7]. Energy impact due to the dropped anchor on pipes as stated in DNV-RP-F107 is as follows [2]:

a. Energy Terminal
\[ E_T = \frac{m \cdot g}{C_D \cdot A} \left( \frac{m}{\rho_{\text{water}}} \cdot V \right) \]  
\[ b. \quad \text{Velocity Terminal} \]
\[ E_T = \frac{1}{2} \cdot m \cdot v_f^2 \]  
\[ c. \quad \text{Added Mass} \]
\[ E_T = \rho \cdot C_a \cdot V \]  
\[ d. \quad \text{Impact Energy} \]
\[ E_T = E_T + E_A = \frac{1}{2} (m + m_a) \cdot v_f^2 \]  

Where: \( m = \) Anchor Massa (kg); \( \rho = \) Sea Water Mass (1025 kg/m³); \( V = \) Anchor Volume (m³); \( C_D = \) Drag coefficient; \( A = \) Anchor Surface Area (m²).

2.2. Draggged Anchor Energy Analysis

The tensile energy due to dropped anchor that pulls to the pipe as stated in DNV-RP-F107 and DNV-RP-F111 is as follows [3]:

a. Impact Energy

Steel Impact Energy Dragged Anchor as following calculation
\[ E_s = R_{fs} \cdot \frac{1}{2} \cdot m_1 \cdot (C_h + V)^2 \]  

Hydrodynamic Mass Energi
\[ E_a = R_{fa} \cdot \frac{\alpha \cdot m_p \cdot D}{(\beta + 1)} \cdot \left[ \frac{F_b}{a \cdot m_p} \right] \cdot \left[ \frac{(\beta + 1)}{\beta} \right] \leq \frac{1}{2} \cdot m_a \cdot (C_h \cdot V)^2 \]  

Impact Energy
\[ E_{\text{impact}} = E_s + E_a \]  

b. Pull-Over Energy

Downward Force
\[ E_z = R_p \cdot (0.2 + 0.8 \cdot e^{-2.5 \cdot H}) \]  

Pull Over Load Duration
\[ E_p = C_T \cdot C_F \cdot (m_1 / k_w)^{1/2} + \delta_p / V \]  

Pull Over Energy
\[ E_{po} = F_z + T_p \]  

c. Hooking Energy
\[ E_H = EP + EK \]  

Where: \( R_s = \) Steel mass associated; \( m = \) Anchor Weight (kg); \( \alpha = \) Coefficient of Impact Velocity; \( M_h = \) Hydrodynamic Weight; \( V = \) Speed (m/s); \( H = \) Dimensionless Height; \( OD = \) Out Side Diameter of (m). The energy of total from anchor withdrawal is [3]:
\[ E_{\text{total}} = E_{\text{impact}} + E_{po} + E_H \]  

2.3. Energy Analysis of Anchor Penetration On Seabed

Along a 14km pipeline will be buried se within 2 meters in accordance with the Prime Minister of Transportation 129 2016 except at the crossing [10]. Therefore the energy needed by the anchor to land before reaching the pipeline needs to be calculated.

a. Energy Penetration
\[ E_P = 0.5 \cdot \gamma \cdot D \cdot N_y \cdot A_r \cdot z + \gamma' \cdot z^2 \cdot N_q \cdot A_r \]
Where: \( \gamma = \text{Sea Water Mass kg/m}^3 \); \( A_p = \text{Surface Area Pipe} \); \( D = \text{Diameter of pipe (m)} \); \( z = \text{Anchor penetration on seabed} \). Based on the above equation we can find out the penetration energy and the penetration depth of the anchor on the seabed.

3. Result and Discussion

3.1. Design Data dan Assumption

Coordinates and sea maps of 20inches submarine gas pipelines starting from the GAS Offloading Platform Center up to 6°08'28.903"S/107°44'33.571"E. After the platform cleared the pipeline through the Riser Center at coordinates 6°08'29.210"S/107°44'33.779"E. Followed by KP 06°08'29.655"S/107°44'33.528"E to KP 9 6°11'05.085"S/107°40'27.040"E. After KP 9 there is an Exsea Subsea pipeline 6°11'09.932"S/107°39'55.619"E up to KP 14.0 6°12'14.629"S/107°38'01.350"E. Specifically the 20inches militant pipeline gas of incoming pipe is presented in the below image:

![Figure 2. Map of Incoming Pipeline Coordinates](image)

3.2. Pipe Specification

The pipe specifications data used in this research subject to incoming pipe. Complete data can be seen in the following table.

| Parameter               | Unit | Value FSRU - ORF |
|-------------------------|------|------------------|
| Pipe Dimension Nominal  | -    | LSAW             |
| Material / Class        | -    | API 5L X65 PSL   |
| Outside Diameter        | mm   | 508              |
| Pipe Thickness          | mm   | 12.7             |
| Corrosion Thickness     | mm   | 3                |
| SMYS                    | Mpa  | 450              |
| SMTS                    | Mpa  | 535              |
| Pipe Density            | kg/m | 7850             |
| Pipeline Length         | km   | 14               |
| Pipe Pressure Design    | Psig | 1160.3           |
| Parameter                              | Unit | Value FSRU - ORF |
|----------------------------------------|------|-----------------|
| Pipe Temperature Design                | °C   | 29              |
| Depth of Sea                           | m    | 14              |
| Concrete Coating Thickness             | mm   | 60              |
| The Breadth of Impacting Object        | m    | 0.03            |
| Depth of Impacting Object              | m    | 0.3             |
| Penetration (CWC) Thickness            | m    | 0.04            |

3.3. Shipping Activities Around Pipeline

Based on the location of the PLTUG incoming project and Looking at sea maps it is known that at least 3 navigation activities need to be considered in risk assessment. The shipping/shipping activities are the activities of ships operating in and out of the Patimban KSOP area, shipping/shipping activities carried out by existing pipe and shipping/shipping activities carried out by Incoming Pipeline itself. The table below shows the ship and anchor type used in analyzing risk assessments.

**Table 2. Vessel Data and Anchor Weight**

| No | Ship Name | Ship type       | LOA (m) | Breadth (m) | GRT  | Anchor Weight (Kg) |
|----|-----------|-----------------|---------|-------------|------|--------------------|
| 1  | A         | Fishing Vessel  | 16,5    | 2,8         | 30   | 150                |
| 2  | B         | Tug Boat        | 29,5    | 10,63       | 289  | 750                |
| 3  | C         | Supply Vessel   | 39      | 9,53        | 600  | 900                |
| 4  | D         | Barge           | 91,44   | 27,4        | 3497 | 1080               |
| 5  | E         | Crane Barge     | 126,2   | 28,6        | 1031 | 1180               |
| 6  | F         | AHTS            | 62      | 16          | 1977 | 1440               |
| 7  | G         | Cement Carrier  | 118,1   | 16,3        | 5003 | 2475               |
| 8  | H         | LNG             | 285,1   | 43,4        | 97897| 9950               |

Refer to above data, the vessels are grouped based on are 3 (three) water depths reviewed, the draft of the ship that can pass the crossing, namely the depth of the sea 6.3 meter and the ship that can only pass through the pipeline outside the crossing point. In this case, there namely 6-meters crossing, 10 meters, and 14 meters deepest. Vessels that can pass through the crossing pipe are ships that their draft not exceeding 4.5 meters. It considering to the height of the crossing, from seabed and keel clearance of the ship. The ships are:

1. Fish Boat with a size of 30 GT and anchor weight of 150 kg
2. Tug Boat with a size of 289 GT and an anchor weight of 750 kg
3. Offshore Supply Ship with 900 GT size and 900 kg anchor weight
4. Barge / Barge with a size of 3497 GT and anchor weight of 1080 kg
5. The Crane Barge is 1100 GT in size and has an anchor weight of 1180 kg
6. AHTS ship with a size of 1997 GT and anchor weight of 1440 kg
3.4. The Result of Frequency and Consequence Analysis.

From the assessment and calculation of frequencies and calculations above, a summary of the calculation results is obtained as in the table below:

| Table 3. Frequency Analysis |
|-----------------------------|
| **Anchor Weight** | **Frequency** |
|---------------------|--------------|
| 150 kg (Without Concrete Coating) | 3.35E-06 |
| 150 kg (With Concrete Coating) | 3.55E-06 |
| 750 kg (Without Concrete Coating) | 4.01E-06 |
| 750 kg (With Concrete Coating) | 4.21E-06 |
| 1080 kg (Without Concrete Coating) | 4.91E-06 |
| 1080 kg (With Concrete Coating) | 5.11E-06 |
| 1180 kg (Without Concrete Coating) | 5.01E-06 |
| 1180 kg (With Concrete Coating) | 5.21E-06 |
| 2475 kg (Without Concrete Coating) | 6.02E-06 |
| 2475 kg (With Concrete Coating) | 6.22E-06 |
| 9950 kg (Without Concrete Coating) | 8.76E-06 |
| 9950 kg (With Concrete Coating) | 8.96E-06 |

| Table 4. Consequence Analysis |
|-----------------------------|
| **Anchor Weight** | **Dropped Anchor (KJ)** | **Impact Energy** | **Dragged Anchor (KJ)** | **Pull Over Energy** | **Hooking Energy** |
|---------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| 150 kg Without concrete coating | 4.03 | 0.22 | 4.03 | 0.92 |
| 150 kg With 60 mm concrete coating | 4.03 | 0.22 | 3.63 | 0.92 |
| 750 kg Without concrete coating | 17.97 | 1.11 | 28.98 | 6.71 |
| 750 kg With 60 mm concrete coating | 17.97 | 1.11 | 28.98 | 6.71 |
| 1080 kg Without concrete coating | 23.79 | 0.53 | 33.35 | 10.86 |
| 1080 kg With 60 mm concrete coating | 23.79 | 0.53 | 33.35 | 10.86 |
| 1180 kg Without concrete coating | 27.07 | 1.74 | 58.51 | 13.35 |
| 1180 kg With 60 mm concrete coating | 27.07 | 1.74 | 58.51 | 13.35 |
| 2475 kg Without concrete coating | 79.53 | 26.13 | 101.84 | 34.92 |
| 2475 kg With 60 mm concrete coating | 79.53 | 26.13 | 101.84 | 34.92 |
| 9950 kg Without concrete coating | 561.19 | 14.67 | 818.71 | 215.75 |
| 9950 kg With 60 mm concrete coating | 561.19 | 14.67 | 818.71 | 215.75 |
3.5. Risk Matrix
Assessment of risk for the subsea pipeline 20 inches have been carried out and the following is the summary of the risk assessment matrix.

The results of the analysis are displayed in the risk matrix so it can be known the level of potential hazards that occur. Large impact energy will occur if the object has a large mass. Vice versa, the impact energy is relatively small if the mass of the object is small [4]. This conditions because larger objects create higher speeds and higher trajectory. As well as providing a large damage impact on the pipeline onshore and offshore. It can be concluded that the area of impact and drag coefficient has the highest sensitivity and mass and adding the mass coefficient has the lowest sensitivity to the probability of failure [11]. Frequency rank and consequence rank are parameters in risk matrix. The analysis value using to the below table:
Table 5. Risk Assessment Results

| Anchor Mass     | Dropped Anchor (KJ) | Dragger Anchor Impact Energy | Pull-Over Energy | Hooking Energy |
|-----------------|---------------------|------------------------------|------------------|----------------|
| Anchor Mass 150 kg |                     |                              |                  |                |
| Without Concrete Coating | 1A                  | 1A                           | 1A               | 1A             |
| With 60 mm Concrete                     | 1A                  | 1A                           | 1A               | 1A             |
| Anchor Mass 750 kg |                     |                              |                  |                |
| Without Concrete Coating | 1C                  | 1A                           | 1C               | 1B             |
| With 60 mm Concrete                     | 1A                  | 1A                           | 1A               | 1A             |
| Anchor Mass 1080 kg |                     |                              |                  |                |
| Without Concrete Coating | 1D                  | 1A                           | 1C               | 1C             |
| With 60 mm Concrete                     | 1A                  | 1A                           | 1A               | 1A             |
| Anchor Mass 1180 kg |                     |                              |                  |                |
| Without Concrete Coating | 1D                  | 1A                           | 1C               | 1C             |
| With 60 mm Concrete                     | 1A                  | 1A                           | 1A               | 1A             |
| Anchor Mass 2475 kg |                     |                              |                  |                |
| Without Concrete Coating | 1E                  | 1A                           | 1E               | 1E             |
| With 60 mm Concrete                     | 1C                  | 1A                           | 1A               | 1A             |
| Anchor Mass 9950 kg |                     |                              |                  |                |
| Without Concrete Coating | 1E                  | 1C                           | 1E               | 1E             |
| With 60 mm Concrete                     | 1E                  | 1A                           | 1E               | 1E             |

Note:
1A = The frequency of failure is so low it can even be ignored with a dent ratio in diameter <5%; 1B = The frequency of failure is very low and can even be ignored by considering the ratio of dent and diameter 5% - 10%; 1C = The frequency of failure is very low and can even be ignored with consideration of race dent and diameter 10% - 15%; 1D = The frequency of failure is very low and can even be ignored with consideration of race dent and diameter 15% - 20%; 1E = The frequency of failure is very low and can even be ignored with consideration of dent ratio and diameter > 20%.

Figure 4. Risk Matrix Gas Pipeline 20 inch PT JSP
4. Conclusions

Analysis of frequency calculation or the possibility risk of dragged anchors and dropped anchor in shipping activities in the KSOP Patimban, existing pipe, and Incoming Pipeline is in a small or still safe frequency area. The cause is the volume of shipping activities and the location of the Incoming Pipeline PLTU project which is quite far from the area of service operations.

Analyze the accounting consequences or damage from the risk of dropped anchor and the risk of dragger anchor on sailing activities in the KSOP Patimban, existing pipe, and Incoming Pipeline in the pipeline in the crossing pipe area is in a variety of areas ranging from very small damage to the medium damage but still safe. Analysis of calculation of the consequences or impact damage due to the risk of the dropped anchor and the risk of dragger anchor of the anchor on the pipeline in the outside area of the crossing showed varying results ranging from risk very little to risk in the ALARP area. But by including the effect of immersion of 2 meters, it was found that there was no risk of endangering the pipe lines or at very safe levels. Based on the two points above, it can be concluded that in the 20-inch gas pipelines along 14 km in the Kerawang waters owned by Incoming Pipeline is still safe the risk of shipping activities around the project.

Mitigation of the risk assessment based on the previous analysis and conclusions is as follows: Although from the above risk assessment on the 20-inch gas pipeline crossing section is still at a safe level, but with safety considerations, no ship is allowed to cross the crossing section. As for anticipating extreme conditions such as emergencies from the risk of falling and pulling anchors based on this risk analysis, it is necessary to add protection to the crossing pipe section that can accommodate the risk of dropped and dragged anchor, especially for ships with drafts less than 4.5 m (+/- 2000-3000 GT for Cargo ships and other types) and or having an anchor weight of 1500 kg. As for the 20-inch gas pipeline outside the crossing section based on the results of the risk assessment above, there is no need for additional protection because it is still in a very safe risk area.

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