Risk Assessment of Subsea pipeline using standard DNVGL-RP-F107

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Abstract. To avoid fuel scarcity, exploitation activities must be carried out to meet the needs of oil in Indonesia. In the process of oil exploitation, facilities are needed to carry out a fluid transfer system from one place to another. One way to carry out the process of fluid transfer at an offshore location is the use of an underwater piping system. However, in the transfer of fluid from one place to another there is a danger that can cause failures in the pipeline system. For example, if an underwater gas pipeline is in the shipping lanes, international and national vessels, there is a possibility of danger that could occur due to a third party. In making this thesis the risk assessment is assessed using the DNVGL-RP-F107 standard. Based on the DNVGL-RP-F107 standard, hazards that may occur in underwater gas pipelines are hazards caused by falling or dropped anchors, anchored dragged pipes and destroyed ship (ship sinking). In risk assessment using the DNVGL-RP-F107 standard, the consequence analysis conducted refers to the damage to the subsea pipeline. After getting the analysis results from the index values that have been made, proceed with making a risk representation using the Risk Matrix. Pipelines that have been evaluated and representations in the risk matrix are in the ALARP zone (as low as reasonably practical) and in acceptable zone.

1. Introduction

In order to avoid scarcity, exploration activities are conducted to look for new sources of oil because demand in Indonesia is always increasing. However, the demand that will continue to rise is not accompanied by production capacity and the availability of resources that should be higher than needed. To carry out fuel production activities, a fluid transfer system is needed to move the fluid from one place to another. The process of fluid transfer at offshore locations requires an underwater pipeline system or subsea hose that is vulnerable to damage to the underwater gas pipeline. Pipeline is the part that most often fails at an oil production unit. This is because the pipeline is the largest part of the unit so the chances of failure are also large compared to other equipment. As for several things that can cause leakage or damage to the underwater pipeline, namely due to corrosion, fractures or cracks due to earthquake or landslides, third party damage, corrosion components, pipe design components, components operational inaccuracies, as well as the characteristics of hazardous products and their distribution factors.

Hazard Identification must be done systematically and must be able to cover all possible dangers that might occur in the subsea pipeline. There are many things that are taken into consideration in
classifying the hazard identification. As explained above, the danger that occurs in the offshore pipeline is one of the bases in conducting Hazard Identification. One of them already has a Hazard Identification standard for hazards that might endanger the submarine pipeline, the Standard DNVGL-RP-F107.

DNVGL-RP-F107 standard presents a risk-based approach to assessing accidental external pipeline protection. Recommendations are given for pipe damage capacity and alternative protection measures and for assessment of the frequency of damage and its consequences. Alternative pipeline protection measures are also presented. Where information is applicable, specific values or calculation procedures are recommended. If the information is not available, then a qualitative approach is provided in the Standard.

In this thesis, Company x’s underwater gas pipeline data is used. (Jabung Block, Jambi), data of ships in the vicinity of the Berhala Strait and underwater pipeline to be held. Company x’s has 3 pipes that deliver fluid from onshore to offshore. The data collection is done by observation and by conducting a literature study.

From the occurrence of failures in the operation of the pipeline as well as the advantages and disadvantages in the use of oil and gas pipelines, the risk assessment must be carried out to determine the level of danger, and appropriate mitigation action measures to prevent any losses caused.

2. Methods
Risk assessment carried out includes the calculation of the frequency and consequences of hazards that might occur. For each potential hazard analyzed, the potential impact on the pipeline is evaluated using quantitative analysis which refers to the DNVGL-RP-F107 [3]. In this case study the problem limitation given is the risk that occurs in the offshore pipeline due to external activities or third parties. Frequency is used to describe the possibility per unit time of the event that occurred. Frequency assessment aims to get the possibility that the ship will conduct a hazardous event at a certain time. Before calculating these frequencies, a risk scenario must be designed. The speed of the ship, the opportunity for the ship to be in a critical area, the time it takes for the ship to pass through the critical area and the opportunity for the ship to drop anchor or the chance of the ship sinking on the pipe is used as a reference in calculating the frequency at each hazard that may arise. Then the frequency calculation results are grouped based on the frequency ranking of DNV-RP-F107 which is used as a reference.

### Table 1. Frequency rank DNVGL-RP-F107

| Ranking | Description                                                                 | Annual Frequency |
|---------|-----------------------------------------------------------------------------|------------------|
| 1       | Likelihood of event considered negligible.                                  | $< 10^{-5}$      |
| 2       | Event rarely expected to occur.                                             | $10^{-4} > 10^{-5}$ |
| 3       | Unlikely for a single pipeline, but may happen once a year given a large number of pipelines. | $10^{-3} > 10^{-4}$ |
| 4       | Event individually may be expected to occur during the lifetime of the pipeline. (Typically, a 100 year storm) | $10^{-2} > 10^{-3}$ |
| 5       | Event Individually may be expected to occur more than once during lifetime  | $> 10^{-2}$      |

After analysing the frequency to get the rank frequency to be plotted on the risk matrix, is to determine what consequences might occur to get the magnitude of the Coefficient Rank. DNVGL-RP-F107 classifies the potential consequences that occur in the offshore pipeline, namely classification
based on safety, economic loss, and environment impacts. Consequence ranking is used to estimate the consequences of accidents on underwater pipelines. The DNVGL-RP-F107 standard uses the ranking of consequences that can be seen in Table 2 as follows:

| Dent / Diameter (%) | Damage description | Conditional Probability |
|---------------------|--------------------|-------------------------|
|                     |                    | D1  | D2  | D3  | R0  | R1  | R2  |
| < 5                 | Minor damage       | 1.0 | 0   | 0   | 1.0 | 0   | 0   |
| 5-10                | Major damage       | 0.1 | 0.8 | 0.1 | 0.9 | 0.1 | 0   |
| 10-15               | Leakage anticipated | 0   | 0.75| 0.25| 0.75| 0.2 | 0.05|
| 15-20               | Leakage and rupture| 0   | 0.25| 0.75| 0.25| 0.5 | 0.25|
| > 20                | Rupture            | 0   | 0.1 | 0.9 | 0.1 | 0.2 | 0.7 |

Based on the frequency ranking and the ranking of consequences that have been made before then the risk matrix can be made from the underwater pipeline risk assessment. In the DNVGL-RP-F107 standard, the risk matrix used is 5 x 5. In the DNVGL-RP-F107 standard’s matrix risk there is an area called ALARP (As low as Reasonably practicable). This DNVGL-RP-F107 risk matrix can be seen in Figure 1.

**Figure 1.** Risk matrix standard DNVGL-RP-F107, 2017

After conducting a risk and risk analysis within the risk matrix in the ALARP zone, it is necessary to reduce the risk by conducting an evaluation. In this thesis will analyse potential hazards that may occur, such as sinking vessels.

3. **Calculation and Results**

In this final project, company X’s underwater gas pipeline data is used (Jabung Block, Jambi). Company X’s 3 underwater pipes that have different fluid transfer functions. These pipes include the
following Condensate Pipe (NPS 10 X 8.74mm WT (API 5L-X52)), Propane Pipe (NPS 8 X 8.18mm WT (API 5L-X52)), and Butane Pipe (NPS 6 X 7.11mm WT (API 5L-X52)). The underwater gas pipeline which has a Condensate Fluid transfer function has the following specifications:

| Table 3. Condensate pipe |
|---------------------------|
| **CONDENSATE PIPE DATA**  |
| Pipe Description:         | NPS 10                             |
| Pipe Type:                | 5L-X52                             |
| Pipe Outside Diameter:    | 10 Inch                            |
| Pipe Inside Diameter:     | 245.26 mm                          |
| Wall Thickness:           | 8.74 mm                            |
| SYMS:                     | 358520000 N/m²                     |
| Pipe Concrete Coating:    | Fusion Bonded Epoxy                |
| Concrete Coating Thickness: | 25 mm                             |

| Table 4: Propane pipe |
|-----------------------|
| **PROPANE PIPE DATA**  |
| Pipe Description:     | NPS 8                              |
| Pipe Type:             | 5L-X52                             |
| Pipe Outside Diameter: | 8 Inch                            |
| Pipe Inside Diameter:  | 195.02 mm                          |
| Wall Thickness:        | 8.18 mm                            |
| SYMS:                  | 358520000 N/m²                     |
| Pipe Concrete Coating: | Fusion Bonded Epoxy                |
| Concrete Coating Thickness: | 25 mm                             |

| Table 5: Condensate pipe |
|--------------------------|
| **BUTANE PIPE DATA**     |
| Pipe Description:        | NPS 6                              |
| Pipe Type:               | 5L-X52                             |
| Pipe Outside Diameter:   | 6 Inch                             |
| Pipe Inside Diameter:    | 145.29 mm                          |
| Wall Thickness:          | 7.11 mm                            |
| SYMS:                    | 358520000 N/m²                     |
| Pipe Concrete Coating:   | Fusion Bonded Epoxy                |
| Concrete Coating Thickness: | 25 mm                             |

Based on the location of the pipeline that stretches from Jambi to the FPSO owned by company x data on vessel activity passing around the submarine gas area can be obtained to calculate the frequency and consequences of DNVGL-RP-F107. Data on the number of ships passing around the underwater pipeline is needed to calculate the frequency and consequences explained in DNV-RP-F107. The vessel data to be used is the number of ships passing through the pipe, the ship's speed, the ship's length, the ship's width, and the anchor weight. The data is obtained by observing and conducting related literature studies (Table 6).

| Table 6. Ship data |
|-------------------|
| **No** | **Ship Type**            | **Ship Description**    | **Frequency /Year** | **Range DWT** | **Length (m)** | **Beam (m)** | **Anchor Mass (Ton)** | **Draft (m)** |
|-------|--------------------------|-------------------------|---------------------|---------------|----------------|--------------|-----------------------|---------------|
| 1     | TANKER (For Lifting Oil) | Size Medium Range (MR)  | 48                  | 50000         | 205            | 29           | 8.7                   | 16            |
| 2     | TANKER (For Lifting Oil) | Size Aframax (LR)       | 48                  | 80000         | 245            | 34           | 12.9                  | 20            |
| 3     | TANKER (For Lifting LPG) | Size VLGC                | 24                  | 55000         | 226            | 37           | 8.7                   | 12            |
The frequency calculation is obtained from the possibility of the ship passing around the subsea pipeline and experiencing an emergency condition until it sinks around the critical sinking zone (CSZ). Where CZS is the amount of twice the length of the ship with the diameter of the ship plus the thickness of the coating of the pipe. Then the ship crashed (collision), causing flooding on the hull of the ship. If the ship is made of steel, the ship will sink and hit the pipe below. With the limitations of the data held, several assumptions were taken to provide a limitation on the frequency assessment. Speed 0.25 knots, 0.5 knots and 0.75 knots are assumed at the frequency assessment due to the ship's speed when sinking.

In general, in conducting frequency assessments, annual frequency calculations are performed. Where the annual frequency calculation is done with the following formula:

\[
F_{SV} = P_1 \times P_2 \times P_3 \times P_4 \times P_5 \times P_6
\]

\(F_{SV}\) = Annual frequency of ships sinking and hitting pipes.
\( P_1 \) = The chance of the ship is in the CSZ area.
\( P_2 \) = Opportunity of Ship in an emergency situation.
\( P_3 \) = Opportunity for collision ship when the ship fails engine.
\( P_4 \) = Chance of damage to ship hull during collision.
\( P_5 \) = The chance of the ship sinking after damage to the hull.
\( P_6 \) = Chance of ship sinking in CSZ area.

\( P_6 \) value is the chance of sinking the ship in the CSZ area. Where the P6 value is obtained by calculating the CSZ width. Which CSZ value is obtained from the formula as follows:

\[
CSZ = D + (2 \times T) + (2 \times W)
\]

(2)

\( CSZ \) = Critical Sinking Zone
\( D \) = Pipe Diameter
\( T \) = Concrete Thickness
\( W \) = Max Anchor Width

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**Figure 2.** ETA ship sinking frequency
In the assessment of the frequency of sinking ships (Ship Sinking), an analysis was also carried out on 8 different groups of ships and 3 different pipes. In the following table is an example of the assessment of the frequency of a sinking ship (Ship Sinking) on one of the types of ships, namely Tanker A to the condensate pipe (NPS10).

As can be seen in the table above, the assessment of ship sinking frequencies on Condensate pipes (NPS10) frequency per year. The danger of sinking vessels (Ship Sinking) at subsea pipeline facilities is still below 10^{-5} for all speed scenarios that are there (0.25 knots, 0.5 knots, and 0.75 knots). Based on the calculation results in this table, the frequency of the Tanker A ship sinking on the NPS10 condensate pipe can be concluded to be ranked 1 which refers to the frequency ranking of DNVGL-RP-F107.

In this final project the results of frequency calculation will be presented using event tree analysis (ETA). Event tree analysis can be seen above.

By using the same frequency assessment of the danger of sinking ships (Ship Sinking), then the assessment of the frequency of sinking vessel can be done on 7 other types of ships. The following can be seen in the table below summarizes the frequency assessment of sinking vessels (Ship Sinking) on 3 different pipes and 8 types of vessels.

**Table 8. Frequency of ship sinking for condensate pipe 10”**

| Type of Vessel  | Frequency Rank | 0.25       | 0.5        | 0.75        |
|----------------|---------------|------------|------------|-------------|
| Tanker A       |               | 3.22683E-10/ Rank 1 | 1.61341E-10/ Rank 1 | 1.07561E-10/ Rank 1 |
| Tanker B       |               | 4.608E-10/ Rank 1  | 2.304E-10/ Rank 1  | 1.536E-10/ Rank 1 |
| Tanker C       |               | 1.96067E-10/ Rank 1  | 9.80336E-11/ Rank 1 | 6.53557E-11/ Rank 1 |
| Tugboat        |               | 4.84173E-11/ Rank 1 | 2.42087E-11/ Rank 1 | 1.61391E-11/ Rank 1 |
| Bulk Carrier   |               | 3.07143E-10/ Rank 1  | 1.53572E-10/ Rank 1 | 1.02381E-10/ Rank 1 |
| Passenger Vessel |             | 2.04692E-10/ Rank 1  | 1.02346E-10/ Rank 1 | 6.82036E-11/ Rank 1 |
| Container      |               | 7.62332E-11/ Rank 1 | 3.81166E-11/ Rank 1 | 2.54111E-11/ Rank 1 |
| Fishing Vessel |               | 4.84173E-11/ Rank 1 | 2.42087E-11/ Rank 1 | 1.61391E-11/ Rank 1 |

**Table 9. Frequency of ship sinking for condensate pipe 8”**

| Type of Vessel  | Frequency Rank | 0.25       | 0.5        | 0.75        |
|----------------|---------------|------------|------------|-------------|
| Tanker A       |               | 3.22616E-10/ Rank 1 | 1.61308E-10/ Rank 1 | 1.07539E-10/ Rank 1 |
| Tanker B       |               | 4.6072E-10/ Rank 1  | 2.3036E-10/ Rank 1  | 1.53573E-10/ Rank 1 |
| Tanker C       |               | 1.9603E-10/ Rank 1  | 9.80153E-11/ Rank 1 | 6.53435E-11/ Rank 1 |
| Tugboat        |               | 4.83358E-11/ Rank 1 | 2.41679E-11/ Rank 1 | 1.61119E-11/ Rank 1 |
| Bulk Carrier   |               | 3.07078E-10/ Rank 1 | 1.53539E-10/ Rank 1 | 1.02359E-10/ Rank 1 |
| Passenger Vessel |             | 2.04632E-10/ Rank 1 | 1.02316E-10/ Rank 1 | 6.82108E-11/ Rank 1 |
| Container      |               | 7.62052E-11/ Rank 1 | 3.81026E-11/ Rank 1 | 1.61119E-11/ Rank 1 |
| Fishing Vessel |               | 4.83358E-11/ Rank 1 | 2.41679E-11/ Rank 1 | 1.61119E-11/ Rank 1 |
### Table 10. Frequency of ship sinking for condensate pipe 6”

| Type of Vessel     | Frequency Rank 0.25 | Frequency Rank 0.5 | Frequency Rank 0.75 |
|-------------------|----------------------|--------------------|---------------------|
| Tanker A          | 3.22549E-10/ Rank 1 | 1.61275E-10/ Rank 1 | 1.07516E-10/ Rank 1 |
| Tanker B          | 4.60641E-10/ Rank 1 | 2.30321E-10/ Rank 1 | 1.53547E-10/ Rank 1 |
| Tanker C          | 1.95994E-10/ Rank 1 | 9.79969E-11/ Rank 1 | 6.53312E-11/ Rank 1 |
| Tugboat           | 1.80915E-10/ Rank 1 | 9.04578E-11/ Rank 1 | 6.03051E-11/ Rank 1 |
| Bulk Carrier      | 3.07013E-10/ Rank 1 | 1.53507E-10/ Rank 1 | 1.02338E-10/ Rank 1 |
| Passenger Vessel  | 2.04573E-10/ Rank 1 | 1.02287E-10/ Rank 1 | 6.8191E-11/ Rank 1  |
| Container         | 7.61772E-11/ Rank 1 | 3.80886E-11/ Rank 1 | 2.53924E-11/ Rank 1 |
| Fishing Vessel    | 4.82543E-11/ Rank 1 | 2.41272E-11/ Rank 1 | 11.60848E-11/ Rank 1 |

The value of the consequence of a dropped anchor using the DNVGL-RP-F107 standard at an underwater pipeline facility needs to be carried out several calculations, as follows:

\[ \text{Ek} = \text{Kinetic energy which can be absorbed by the protective} \]
\[ \text{EE} = \text{Effective energy anchor when hitting underwater pipe} \]
\[ \text{E} = \text{The amount of energy the pipe receives from falling anchor.} \]

#### Figure 3. Ship sinking

#### Table 11. Consequences calculation
By using the same consequence assessment of the danger of sinking ships (Ship Sinking), then the assessment of the consequence of sinking vessel can be done on 7 other types of ships. The following can be seen in the table below summarizes the frequency assessment of sinking vessels (Ship Sinking) on 3 different pipes and 8 types of vessels.

### Table 12. Consequence ship sinking for condensate pipe 6”,8”,10”

| Type of Vessel | Effective Energy | Frequency Rank |
|---------------|------------------|----------------|
| Tanker A      | 5436200.48       | 5              |
This damage categories value is calculated based on the ranking of consequence in DNVGL-RP-F107 standard. On Tanker A and Pipa Condensate (NPS10), the damage categories consequence values are obtained as in the table below:

| Level   | Dent/Diameter | Range of Impact Energy |
|---------|---------------|------------------------|
| Level 1 | < 5%          | < 1.40                 |
| Level 2 | 5% - 10%      | 1.40 - 3.96            |
| Level 3 | 10% - 15%     | 3.96 - 7.28            |
| Level 4 | 15% - 20%     | 7.28 - 11.21           |
| Level 5 | > 20%         | > 11.21                |

Based on the parameter values that have been obtained, it can be concluded that the assessment of the consequences due to the drop anchor of the Tanker A type vessel in the Condensate pipe (NPS10), is ranked 5th because the energy received is more than 11.21 kJ. This is because the energy value that can be absorbed by concrete coating is 13100 kJ, while the impact energy value is 5449300 kJ.

After calculating and ranking frequency and consequences due to Dropped Anchor and Ship Sinking using the DNVGLRP-F107 standard, the next step is to incorporate the ranking of frequencies and consequences into the risk matrix 5 x 5. After entering the frequency and consequence ranking into the risk matrix, it can be seen risk of damage to the underwater pipeline due to possible hazards.

If the risk is in the acceptable zone, then mitigation efforts are not necessary but periodic inspection efforts are required. If the risk is in the ALARP zone, mitigation efforts may be undertaken but not mandatory. If the risk is in the not acceptable zone then mitigation efforts are needed to reduce the frequency and consequence value so that after mitigation is carried out, the risk can be in the acceptable zone.
In the risk matrix due to the Dropped Anchor underwater pipeline readings on the risk matrix found that the type of Tanker A and Condensate pipe (NPS10) are at the risk level of the ALARP category.

4. Conclusion
Based on the frequency and consequence calculation, company x’s underwater pipe can be concluded the risk level on risk matrix for all the types of ships are in the ALARP condition. Under these conditions it can be concluded that risk mitigation is not necessary, due to conditions ALARP risk is still acceptable, so mitigation is not needed. However, the frequency level must be maintained and ensured to remain in that condition by conducting periodic inspections of medium underwater gas pipelines reviewed.

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