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Improving the availability of floating hose SPM 165,000 DWT using floating hose stabilizer innovation

Aziz Wicaksono [a,1], ***Hari Fridana*** [a], ***Dalih Fajar Nurjaya*** [a], ***Bambang Adhi Priyambodho*** [b]

[a]*PT Kilang Pertamina Internasional, Indonesia*

[b]*Civil Engineering, Faculcity of Engineering, Sultan Ageng Tirtayasa University, Jenderal Sudirman Street Km. 3 Cilegon, Banten 42435, Indonesia*

[1]Corresponding author: aziz.wicaksono@pertamina.com

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ABSTRACT

Single Point Mooring (SPM) 165,000 DWT (Deadweight Tonnage) is a facility at PT Kilang Pertamina Internasional RU VI Balongan that is used for unloading crude oil from tankers to storage tanks. This SPM is about 15 km from the jetty of PT KPI RU VI Balongan which is connected to two parallel 32 inch diameter submarine pipelines. The SPM is connected to 2 floating hoses of 16 inch diameter and 2 submarine hose strings using a turred system connected to 32 inch submarine pipelines through a PLEM. The PLEM is equipped with valves that can be controlled from the SPM using a control umbilical. The existing condition of the 165,000 DWT SPM was idle and unattended. During this period, two strings of floating hose tangled with each other and damaged the floating hose due to abrasion from overlapping. The occurrence of tangling on the floating hose at the same time and repetitive caused to lose and the 165,000 DWT SPM could not be operated and had an impact on the supply of crude oil to the PT KPI RU VI Balongan. In addition, floating hose leaks cause oil spills and pollute the surrounding aquatic environment and require large recovery costs to clean up the oil spills. This research aims to reduce the risk of tangling between 2 floating hoses by applying a floating hose stabilizer at several floating hose joints. The research method begins with a survey of existing floating hose conditions that experience tangling. Furthermore, analysis and modeling of the floating hose system is carried out. Then design and fabrication of floating hose stablizer for tangling prevention. And the results of the analysis and field conditions after the installation of the floating hose stabilizer are reduced potential tangling on 2 floating hoses thereby reducing the risk of losses both financial and environmental.

ABSTRAK

Single Point Mooring 165.000 DWT merupakan sarana dan fasilitas di PT. Kilang Pertamina Internasional (KPI) RU VI Balongan yang digunakan untuk unloading crude oil dari tanker ke tangki penyimpanan. SPM ini berjarak sekitar 15 km dari jetty PT. KPI RU VI Balongan yang dihubungkan dengan dua submarine pipelines paralel berdiameter 32 inch. SPM ini disambungkan pada 2 floating hose yang berdiameter 16 inch dan 2 submarine hose strings menggunakan turred system yang terhubung dengan 32 inch submarine pipelines melalui Pipe Line End Manifold (PLEM). PLEM dilengkapi dengan valve yang dapat dikontrol dari SPM menggunakan sebuah control umbilical. Selama periode pengapalan atau selama kondisi idle, dua string floating hose saling bersilangan/melilit satu sama lain (tangling) dan merusak floating hose akibat abrasi karena saling tumpang tindih. Terjadinya tangling pada floating hose dalam waktu bersamaan dan repetitive menyebabkan kerugian perusahaan mencapai 9,7 Miliar rupiah dan SPM 165.000 DWT tidak dapat dioperasikan dan berdampak pada supply crude oil ke kilang PT KPI RU VI Balongan berhenti. Selain itu, kebocoran floating hose berpotensi menimbulkan ceceran minyak dan mencemari lingkungan perairan sekitar dimana akan membutuhkan biaya recovery yang besar untuk membersihkan ceceran minyak tersebut. Penelitian ini bertujuan untuk mengurangi resiko terjadinya tangling antar 2 floating hose dengan mengaplikasikan floating hose stabilizer di beberapa joint floating hose. Metode penelitian dimulai dengan survey kondisi existing floating hose yang mengalami tangling. Selanjutnya dilakukan analisa dan pemodelan sistem floating hose. Kemudian dilakukan desain dan pabrikasi floating hose stablizer untuk pencegahan tangling. Dan hasil analisa dan kondisi lapangan setelah pemasangan floating hose stabilizer adalah tidak terjadi tangling pada 2 floating hose sehingga mengeliminasi resiko kerugian baik finansial manupun lingkungan.

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1. Introduction

PT Kilang Pertamina Internasional RU VI Balongan is a company engaged in oil and gas processing. There are various equipment used to process crude oil into products that are ready to use as we know Pertalite, Pertamax, Dexlite and so on. In the processing process before becoming a commonly used fuel oil, there are several processes that must be passed such as fractionation, hydro treating and others.

Before the crude oil enters the processing area at the refinery, the crude oil carried by the tanker will be stored into the tank. The process of moving crude oil from the tanker to the refinery storage tank is through the 165,000 DWT Single Point Mooring (SPM). SPM 165,000 DWT is a facility at PT Kilang Pertamina Internasional RU VI Balongan that is used for unloading crude oil from tankers to storage tanks.

The crude oil transfer process is one of the important things in oil and gas companies, where the transfer of raw materials into the processing location requires accuracy and foresight to avoid detrimental things for both the company and the environment. As happened in 2008, where crude oil from the tanker to the storage tank experienced a floating hose leak and polluted the aquatic environment around RU VI Balongan. This is very detrimental to the surrounding aquatic environment and also the company's financial losses for the cost of recovering the pollution. The floating hose damage was caused by 2 floating hoses overlapping/tangling in the idle position. When the floating hose overlaps and is exposed to sea waves, the floating hose will rub and cause tear/damage to the floating hose. (PT. KPI RU VI Balongan, 2008)

Figure 1. **Floating Hose damaged due to tangling (PT. KPI Unit VI Balongan)**

For this reason, it is necessary to prevent and maintain the floating hose so that nothing harmful happens to both the company and the environment. In this study, efforts to prevent tangling are carried out by adding floating hose stabilizers to several joints. These efforts are made with the aim of preventing the position of the floating hose from overlapping and preventing friction between the floating hose so that damage does not occur, so that the same mistake does not occur in the future.

Research conducted by [1] from the Department of Energy and Electrical Engineering University of Humanities, Science and Technology published under the title : “Spatial Configuration and Static Characteristics of Hoses in Deep-sea Ore Conveying System” states, the analysis result of the ore conveyor hose space configuration shows that a hose with a buoyancy ball has a larger effective working area and a better effect than a hose without a buoyancy ball. The movement speed and movement pattern of the mining vehicle have a great influence on the horizontal force of the connection between the hose and the mining vehicle and the shape of the hose. If the mining vehicle moves back and forth on the X-direction, the shape of the hose changes greatly, which is very unfavorable to the work of the conveying system [1].

In research conducted by [2] from the Department of Engineering Lancaster University published under the title: "An Overview on Bonded Marine Hoses for Sustainable Fluid Transfer and (Un)Loading Operations via Floating Offshore Structures (FOS)" states, the methodology used is to compare hose test methods, hose modeling, storage issues and installation advantages during application in SPM. From the bending behavior of the hose, it was found that there is a snaking phenomenon and hydrodynamics of the marine hose. From the database information obtained from stakeholders and reported incidents, the most common damage is on the marine hose cover [2].

Research conducted by [3] in China with the title: "Wave Loads Computation for Offshore Floating Hose Based on Partially Immersed Cylinder Model of Improved Morison Formula". The method used is the development of Morison Formula from offshore floating hose partially immersed cylinder model. The improvement of the Morison Equation aims to determine a partially immersed cylinder model which has the morphology and mechanical characteristics of a floating hose. As when the floating hose is placed at depths of 6 meters and 3 meters, the wave loads based on Morison Equation will be more precise than before. The accuracy of the wave load can be improved up to 15% [3].

Research conducted by [4] with the title: "Snaking of Floating Marine Oil Hose Attached to SPM Buoy". The method used is an analysis model presented for the transverse vibration of a semi-infinite beam due to longitudinal harmonic motion at the tip. This model is applied to the "snaking" behavior of the floating hose attached to the SPM. The surge response of the SPM to waves causes the connected floating hose to snake. Analytical predictions of snake frequency and wavelength were verified in the test results of this model. It is difficult to assess the accuracy of this study, but the results suggest 30% [4].

Research conducted [5] with the title: "Qualification of a Cryogenic Floating Flexible Hose Enabling Safe and Reliable Offshore LNG Transfer for Tandem FLNG Offloading Systems". The research method used is a concept assessment, design and test using laboratory tests and prototype tests. By enabling the offshore transfer of LNG with a tandem arrangement, the cryogenic floating hose will pioneer a safety step change in this critical operation. It will also allow FLNG projects to be considered under more difficult conditions without excessive downtime due to the availability of offloading systems and with significantly reduced risk [5].

2. Theoretical Foundation and Research Methodology

2.1. Turret Buoy

Figure 2. Turret Buoy

Turret buoys usually have an enclosed center well and deck house. On a turret buoy, the mooring platform, cargo piping support and counterbalance platform are integrated into a buoy body that rotates around the center of the turret. The buoy body provides buoyancy and because the buoy body rotates, it allows the tanker to adjust to the wind direction around the turret. An anchor chain is attached to the lower end of the turret, which is connected to the float body through large-diameter bearings. Cargo piping flows through the center space of the turret, through the cargo swivel and over the buoy deck, to the marine piping connection for the floating hose array [6].

2.2. Regular Wave Theory

The motion of water, like waves, is determined by the laws of mechanics, which are essentially conservation laws related to the medium. The easiest to understand is the conservation of mass, where mass can neither be created nor removed. If a canal with parallel walls and a horizontal bottom is depicted, with waves moving along the canal but with no variation of motion in the transverse direction, as shown in Figure 3. The problem that then needs to be solved is how to express wave quantities, such as length and period, in terms of known properties, e.g. water depth, gravity and so on.

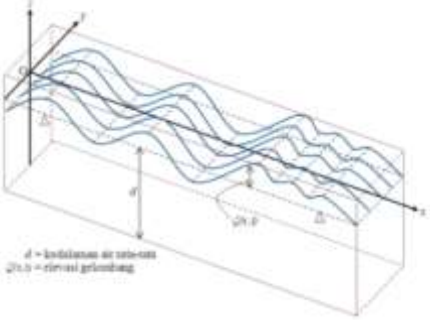

Figure 3: Regular Wave

2.3. Basic Concept of Sea Building Movement

The basic concept of marine building movement according to Comstock (1977) in the book [7]. It can be explained that by considering a cylinder of diameter D that is freely floating placed in a harmonic or sinusoidal wave propagation field. The wave is assumed to have a length much greater than the diameter of the cylinder, as shown in Figure 4.

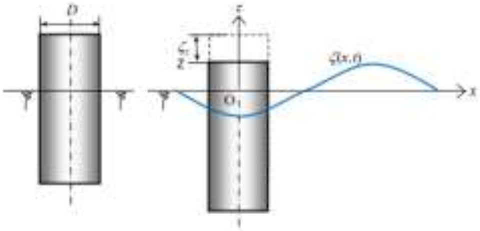

Figure 4: Basic Concept of Sea Building Movement

When a wave passes through a cylinder, the surrounding fluid exerts hydrodynamic forces on it. These forces consist of two components, the steady component of excitation, known as first-order forces, which will cause the cylinder to oscillate linearly and proportionally to the wave height. The second component is the forces that arise due to non-linear effects, with a relatively small intensity and proportional to the square value of the wave height, which are referred to as second-order forces [7].

The pressure force consists of the return hydrostatic force and the hydrodynamic force. The hydrostatic force F_k is the force generated by the volume of fluid that is pushed due to the cylinder moving. In Figure 4 as the wave propagates, the cylinder is considered to move with 1-degree of freedom in the direction of the vertical axis z, referred to as heave motion. In this motion, when the cylinder moves down by ζ_z it will experience additional volume, and subsequently a displacement $of\,\Delta = \rho g \zeta_z(\frac{\pi}{4}D^2)$. The hydrostatic force will be linearly correlated to the elevation or displacement of the motion, and act against the motion. So it can be written:

$$F_k = -k\zeta_z, \tag{1}$$

where k is the return force coefficient and ζ_z is the displacement of the heave motion.

2.4. Hydrodynamics of Marine Building Movement

The motion of marine structures as illustrated simply in the form of a floating cylinder in the above subchapters clearly shows that the main factor at play is fluid dynamics. Therefore, problem solving must begin with an understanding of fluid dynamic behavior, which has been presented in the study of regular waves by correlating the fluid velocity of a particular flow pattern to the fluid pressure that is then generated. A number of fluid velocity components for a given flow pattern can basically be obtained by spatially deriving them from a specific velocity potential function.

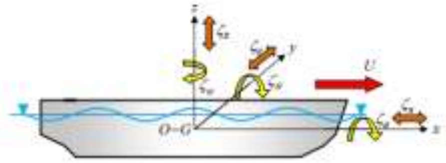

Figure 5. Sea Building Movement

It is well known that marine structures such as the one shown in Figure 5, when subjected to wave excitation, experience oscillatory motions in 6 degrees of freedom. Using the right-hand axis convention, the motions are three translational motions in the x, y and z axis directions, respectively *surge* (ζ_x or ζ_1), *sway* (ζ_y or ζ_2) and *heave* (ζ_z or ζ_3). Furthermore, the sea building also moves rotationally about the three axes are *roll* (ζ_ϕ or ζ_4), *pitch* (ζ_θ or ζ_5) and *yaw* (ζ_ψ or ζ_6).

If, when the seabed oscillates in the six modes of motion, the viscosity effect is temporarily ignored, so that the fluid can be assumed to be irrational, the problem can be defined by applying potential theory, as carefully described by Salvesen et al (1970). It is known that the total velocity potential Φ(x,y,z,t) must satisfy Laplace's equation, and furthermore in this case it must also satisfy the boundary conditions on the hull surface of the marine building:

$$\frac{DF}{Dt} = 0 \tag{2}$$

This equation is known as the *substantial derivative of the* hull surface defined in the function F(x,y,z)=0. If the function is replaced by the pressure on any unit surface area then :

$$\frac{Dp}{Dt} = -\rho\frac{D}{Dt}\left(\frac{\partial\Phi}{\partial t} + \frac{1}{2}|\nabla\Phi|^2 + gz\right) = 0 \tag{3}$$

Physically, equation (3) above means that no fluid penetrates the sea building. The term in brackets is the Bernoulli equation. The velocity potential in the equation can be divided into two, namely: first, the time-independent steady contribution generated by the forward motion rate and second, the time-dependent component due to the incident wave system and the unsteady motion of the seawall [7].

2.5. Response Amplitude Operator (RAO)

Information on the motion characteristics of marine structures is generally presented in graphical form, where the abscissa is a frequency parameter, while the ordinate is the ratio between the amplitude of the motion at a given method (ζ_{k0}) and the amplitude of the wave, (ζ_0). The frequency used as the abscissa can be the incident wave, (ω), the frequency of the impact wave (ω_e) or a non-dimensional frequency. The non-dimensional frequency, whether associated with incident waves or impact waves, is a parameter obtained from the wave frequency by taking into account the length of the building (L) and the acceleration of gravity (g) as follows:

$$\omega' = \frac{\omega}{\sqrt{g/L}} \tag{4}$$

The motion *response*, or commonly known as *response amplitude operator* (RAO), for *translational* motion, *yi, surge*, *sway* and *heave* (k = 1,2,3 or x,y,z) is a direct comparison between the amplitude of the motion compared to the amplitude of the incident wave (both in units of length):

$$RAO = \frac{\zeta_{k0}}{\zeta_0}(m/m) \tag{5}$$

While the non-dimensional response or RAO of rotational motion, yi. roll. Pitch and yaw (k=3,4,5 or θ,ϕ,ψ) is the ratio between the amplitude of the rotational motion (in radians) and the wave slope, which is the product of the wave number $k_w = \omega^2/g$, and the amplitude of the incident wave:

$$RAO = \frac{\zeta_{k0}}{k_w\zeta_0} = \frac{\zeta_{k0}}{(\omega^2/g)\zeta_0} \tag{6}$$

2.6. Data

2.6.1. Field Survey

A field survey was conducted to determine the existing condition of the floating hose on the 165,000 DWT SPM. Based on the survey results, information was obtained that the existing floating hose experienced tangling at several joints, namely between the 4th and 20th joints. The crossing distance is about 3-4 joints/section. This crossing resulted in 15 floating hoses experiencing severe damage to the innermost layer of the floating hose.

2.6.2. Data Collection

To analyze the motion of the floating hose on the 165,000 DWT SPM, data on the SPM, floating hose, and tanker are required. In addition, environmental input data is also needed, including wave, wind and current data, which are obtained from metocean data. These data include:

1. 165,000 DWT SPM Data

   The 165,000 DWT SPM data includes:
   - Length : 12.702 m
   - Breadth : 11.000 m
   - Depth : 10.641 m
   - Weight : 368.200 m
2. Floating Hose Data

   The floating hose on the 165,000 DWT SPM consists of 2 lines, each of which has 25 hoses with the following sizes:
   - Length (L) : 10,67 m
   - End outer diameter (OD) A : 776 mm
   - Body outer diameter (OD) B : 706 mm
   - Inner diameter (ID) : 387 mm
   - Weight (W) : 2280 kg
   - Pressure rating : 21 bar
   - Min. burst pressure : 105 bar
3. Tanker Data

   The tanker data is as follows:
   - Deadweight (DWT) : 160,000 DWT
   - Length overall (DWT) : 149,962 DWT
   - Length perpendicular (L_{OA}) : 274,48m
   - Breadth (L_{PP}) : 264,00 m
   - Draft (B) : 48,00 m
   - Height (T) : 16,279 m

2.6.3. Hydrodynamics Properties Calculation

Modeling is done according to the dimensions found in point 2.6. After modeling, the hydrodynamics properties of the SPM and tanker can be calculated, including the following:

1. Hydrodynamics Properties of 165,000 DWT SPM

Table 1. Hydrodynamics Properties Data of 165,000 DWT SPM

No.	Item	Value	Unit
1	LCG	-0,007	m (midship)
2	TCG	0,298	M
3	VCG	0,129	m (water surface)
4	Disp.	369.000	Tons
5	Kxx	5,157	-
6	Kyy	6,016	-
7	Kzz	3,097	-

Notes: SPM data includes additional weight due to landing boat and LDS modifications. This condition is at maximum SPM draft condition.

2. Tanker Hydrodynamics Properties

   The ship used as a reference for simulating motion floating hose is KMT. Mabrouk with hydrodynamics properties data under full load conditions as follows:

Table 2: Tanker Hydrodynamics Properties Data

No.	Item	Value	Unit
1	LCG	134.770	m (AP)
2	TCG	0,000	M
3	VCG	-2,634	m (water surface)
4	Disp.	173.568	Tons
5	kxx	11,550	-
6	kyy	160,178	-
7	kzz	159,761	-

2.6.4. Floating Hose Motion Analysis

Seven simulations were conducted which are the results of variations using Ansys Aqwa software. The seven simulations will be varied against 3 wave headings, namely 90°, 135°, and 180°. The three wave variations are also varied again against the direction of incoming wind and current. The direction of incoming waves, wind and current are varied collinearly and non-collinearly.

2.6.5. Analysis Procedure

Using the available vessel documents, the following basic input data was generated for the MOSES (Offshore Simulation Software):

- The resulting hull input offsets use various ship scantling plans to capture the column, bracing and shape of the underwater hull.
- The wind and underwater hull/column/bracing areas were calculated using various general arrangement drawings of the ship and the area values were used as input into the MOSES program to calculate the corresponding forces.

The following is the data generated by MOSES:

- Respond Amplitude Operators (RAO)
- Added Inertia Coefficient
- Linear Radiation Damping Coefficient
- Linearized Wave Frequency Forces

These operations are analyzed using the Orcaflex program. The Orcaflex program provides fast and accurate analysis of catenary systems such as analysis of moorings, flexible risers and umbilical cables under wave and current loads and externally performed motions. The analysis procedures for operation and survival are listed below:

- Three-dimensional diffraction/radiation analysis was performed using MOSES to calculate the hydrodynamic coefficients, as we added mass, radiation damping, linear wave force, wave drift force and motion RAO.
- The mooring lines are Orcaflex, and also incorporate hydrodynamic properties generated by MOSES software. The barge is treated as a rigid body with 6 degrees of freedom, 3 translational and 3 rotational. The equations of motion have the following contributions. Regular wave time domain simulations are performed with the associated maximum height and wave period. The safety factors of the mooring lines are compared with the requirements of ABS rules, Rules for Building and Classing Single Point Mooring.

Furthermore, the variations are simulated with the following loading case variations:

- Operating Conditions
  The operating environmental conditions for an SPM are defined as the maximum sea state at which the vessel is allowed to remain moored to the SPM without exceeding the allowable load and required pressure. For this study, these conditions are applied to the fully loaded condition of the tanker. Ballast conditions need to be performed to analyze the effect of wind due to the higher rising hull.
- Storm Conditions
  Storm conditions for SPM design are defined as environmental conditions with maximum winds, waves and associated currents based on a 100-year recurrence interval. Under these conditions no vessel is moored to the SPM system, unless the SPM system is specifically designed for this loading environment.

In this analysis, only intact mooring line conditions are carried out where damaged mooring line conditions are not considered. Next, the Mooring analysis will be performed by considering the load direction as below conditions. This case also considers 2 conditions as mentioned earlier, full load and tanker ballast conditions:

- Collinear
  Unidirectional - the direction of environmental loading is in line with one of the mooring chains (not currently considered in this analysis) between - the direction of wave loading is between two (2) mooring chains (considered in the analysis).
- Non-Collinear
  Wind direction 30° and current 45° relative to the waves. Unidirectional - the direction of environmental loading is in line with one of the mooring chains (currently not considered in this analysis). Between - the direction of wave loading between two (2) mooring chains (considered in the analysis).

2.6.6. Mooring Tension Analysis

The mooring analysis was conducted using Orcaflex software to determine the maximum tension value of the mooring system used in the 165,000 DWT SPM due to the influence of the SPM itself, floating hose, and tanker movements.

2.6.7. Loading/Unloading System Data

1. SPM Buoy
   The loading/unloading system consists of a number of components, which are detailed in this section. The SPM buoy is attached with two subsea hoses in a "Chinese Lantern" configuration to the PLEM on the seabed. The vessel, which will have a maximum capacity of 165,000 DWT, was moored to the buoy by two Nylon hawser lines. Floating loading hoses were attached to the SBM buoy to enable the flow of production fluids from/to the vessel.
2. Subsea Hose
   The bonded hose connecting the buoy to the PLEM on the seabed is assumed to be in the "Chinese Lantern" configuration. This configuration allows translational movement of the buoy. The configuration incorporates a 20" double hose. The larger the hose diameter, the more sensitive the configuration is to the risk of bending. This is because larger hoses have a higher MBR.
3. Floating Loading Hose
   The length of the floating hose depends on the length of the hawser and the distance of the manifold on the deck of the ship and the maximum freeboard dimension of the ship. The length also depends on the extension of the hawser, the radius of the kinked hose and the diameter of the float. The floating hose has 25 rope line sections of End manifold line, main line, tail hose, and tanker rail barbell hose with a total length of about 270 m have been considered in this mooring analysis.

3. Analysis and Discussion

3.1. Simulation of Floating Hose Motion

Geometry Settings

In this floating hose movement simulation, there are 2 part body models configured in the simulation, namely the SPM and tanker models. Meanwhile, the floating hose itself is modeled in the form of a catenary section.

1. Simulation 1
   Simulation 1 is where the floating hose is not installed with a crossover and stabilizer during idle conditions (not connected to the tanker).

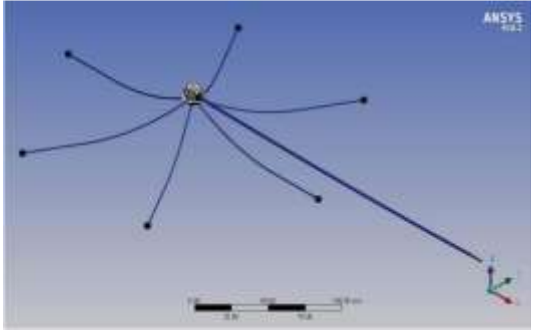

Figure 6. Simulation Geometry 1

2. Simulation 2
   Simulation 2 is where the floating hose is not installed with a crossover and stabilizer during operating conditions (connected to the tanker).

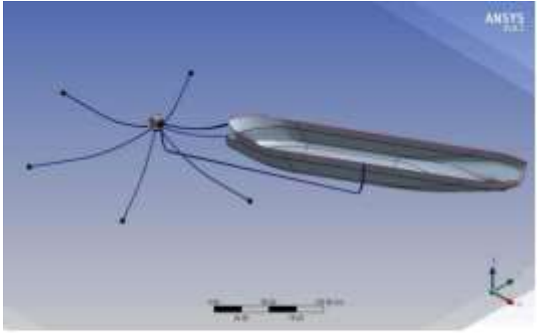

Figure 7. Simulation Geometry 2

3. Simulation 3
   Simulation 3 is where the floating hose is installed with a crossover but no stabilizer is installed in idle conditions (not connected to the tanker).

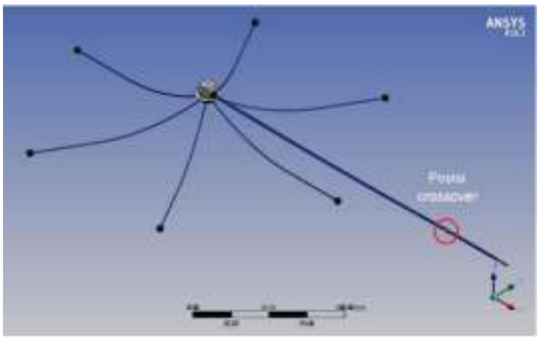

Figure 8. Simulation Geometry 3

4. Simulation 4
   Simulation 4 is where the floating hose is installed with a crossover but no stabilizer is installed under operating conditions (connected to the tanker).

5. Simulation 5
   Simulation 5 is where the floating hose is not installed with a crossover but a stabilizer is installed in idle conditions (not connected to the tanker).

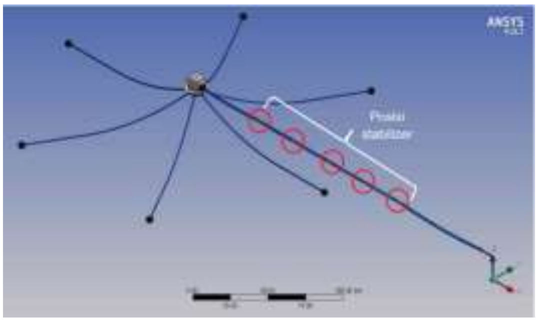

Figure 9. Simulation Geometry 5

6. Simulation 6
   Simulation 6 is where the floating hose is not installed with a crossover but a stabilizer is installed under operating conditions (connected to the tanker).

7. Simulation 7
   Simulation 7 is where the floating hose is installed with a crossover and stabilizer in operating condition (connected to the tanker).

3.2. Motion Simulation Results

3.2.1. Tanker Response Amplitude Operators (RAO)

The results of the Response Amplitude Operators (RAO) of the tanker can be seen in Figure 10 to Figure 15. This tanker RAO value is used to simulate the motion of the floating hose under operating conditions.

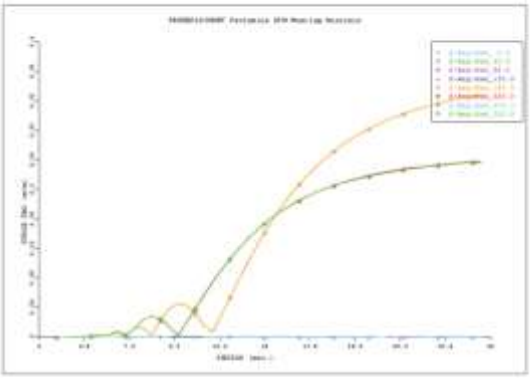

Figure 10. RAO Surge

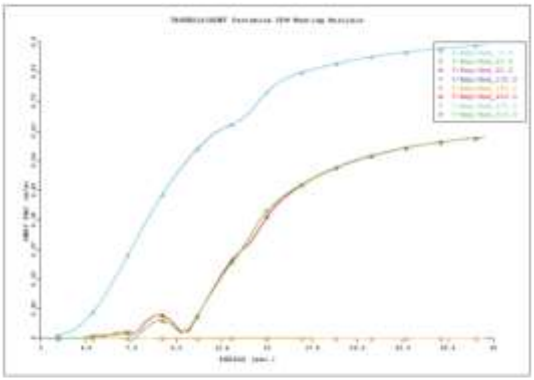

Figure 11. RAO Sway

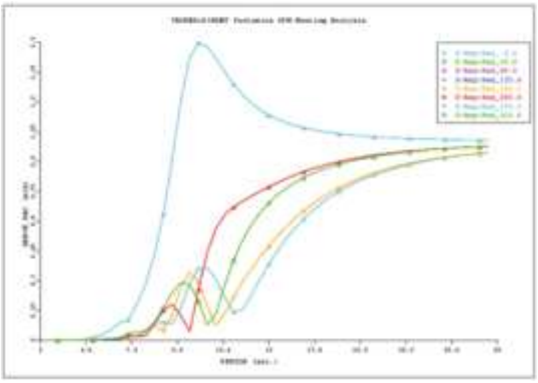

Figure 12. RAO Heave

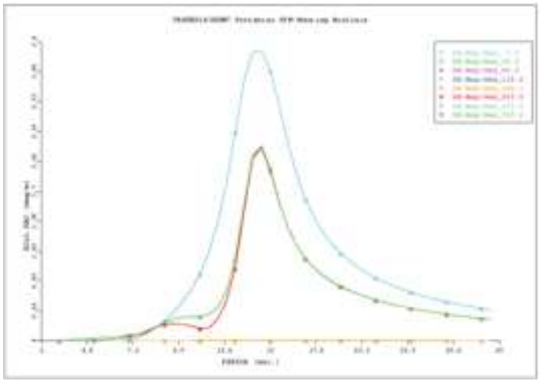

Figure 13. RAO Roll

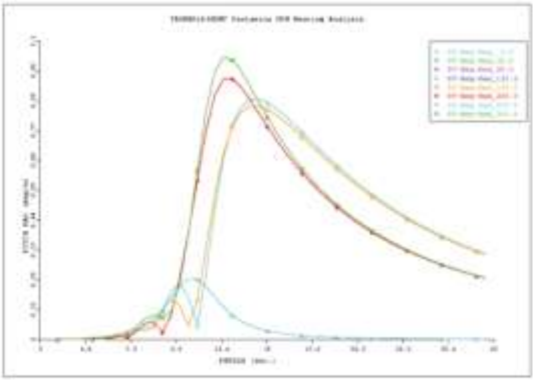

Figure 14. RAO Pitch

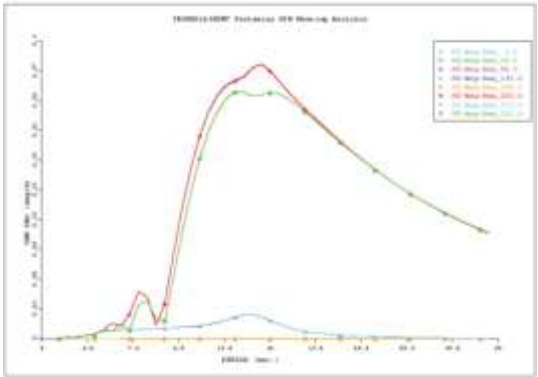

Figure 15. RAO Yaw

3.2.2. Wave Spectrum

For motion response analysis, the JONSWAP wave spectrum was used at a significant wave height (Hs) of 2.68 m, surface current speed (Vs) of 0.64 m/s, and wind speed (Vw) of 13.79 m/s. The wave spectrum graph used can be seen in Figure 16.

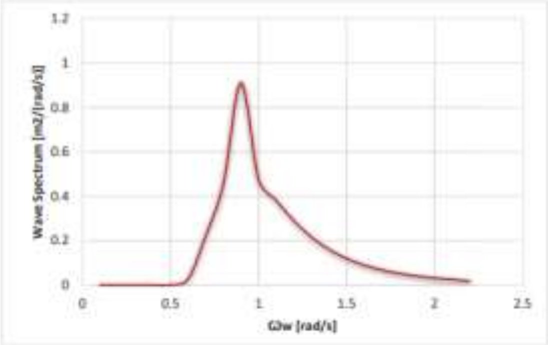

Figure 16. JONSWAP Spectrum

3.2.3. Motion Analysis Evaluation

1. Simulation 1

   Simulation 1 is a condition where the floating hose is not installed with a crossover and stabilizer at idle (not connected to the tanker). After simulation, it was found that the floating hose experienced tangling when the wave heading was 180^0 and 90^0 as can be seen in Table 3. As for the visualization, it can be seen in Figure 17 to Figure 19.

Table 3. Evaluation of Motion Simulation 1

No.	Wave Heading (°)	Clash	Crossing	Position of Clash/Crossing*	Check
1	180	Yes	Yes	Middle	Evaluated
2	135	No.	No.	-	OK
3	90	Yes	Yes	Middle and End	Evaluated

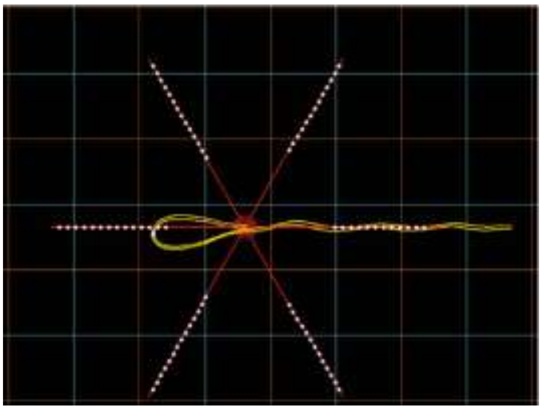

Figure 17. Wave heading 180º

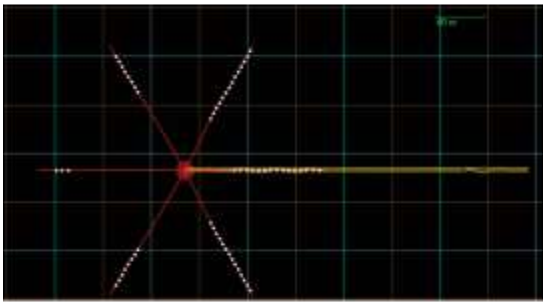

Figure 18. Wave heading 135º

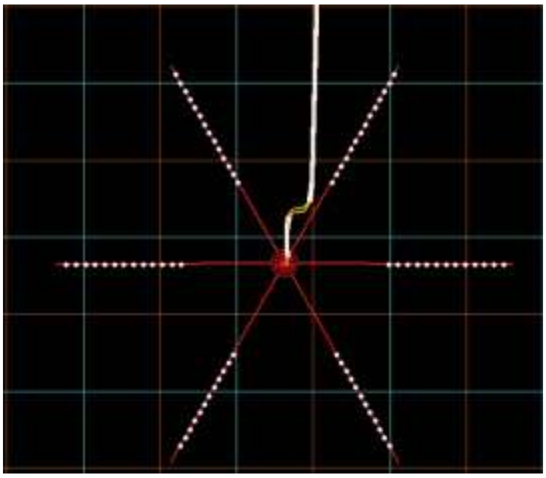

Figure 19. Wave heading 90º

2. Simulation 2
   Simulation 2 is a condition where the floating hose is not installed with a crossover and stabilizer during operating conditions (connected to the tanker). After simulation, it was found that the floating hose experienced tangling when the wave heading was 180^0, 135^0 and 90^0 as can be seen in Table 4. As for the visualization can be seen in Figure 20 to Figure 22.

Table 4. Evaluation of Motion Simulation 2

No.	Wave Heading (º)	Clash	Crossing	Position of Clash/Crossing*	Check
1	180	Yes	Yes	Top	Evaluated
2	135	Yes	Yes	Middle and End	Evaluted
3	90	Yes	Yes	Middle and End	Evaluated

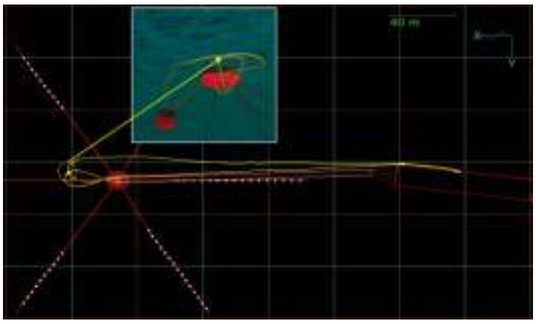

Figure 20. Wave heading 180º

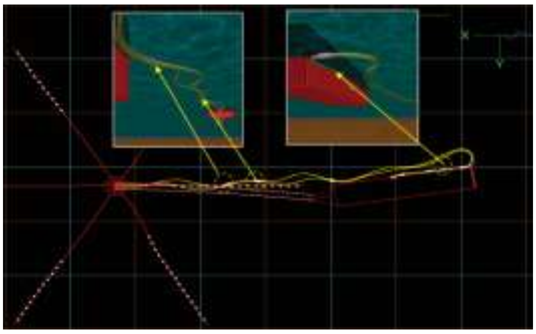

Figure 21. Wave heading 135º

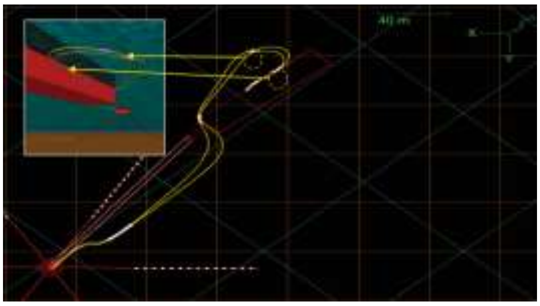

Figure 22. Wave heading 90º

3. Simulation 3

   Simulation 3 is a condition where the floating hose is installed with a crossover but no stabilizer is installed in idle conditions (not connected to the tanker). After simulation, it was found that the floating hose experienced tangling as can be seen in Figure 23.

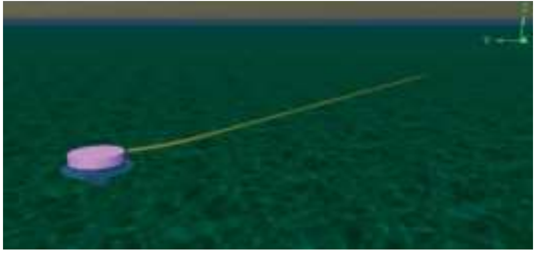

Figure 23. Visualization of simulation 3

4. Simulation 4

   Simulation 4 is a condition where the floating hose is installed with a crossover but no stabilizer is installed under operating conditions (connected to the tanker). After simulation, it was found that the floating hose experienced tangling as can be seen in Figure 24 and Figure 25.

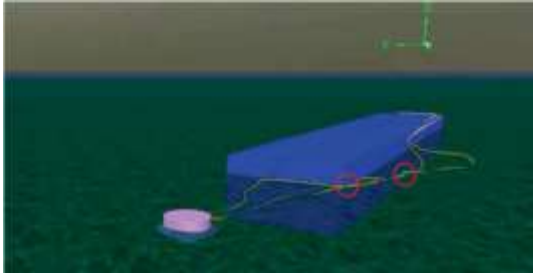

Figure 24. Collinear

Figure 25. Non-collinear

5. Simulation 5

   Simulation 5 is a condition where the floating hose is not installed with a crossover but a stabilizer is installed in idle conditions (not connected to the tanker). After simulation, it was found that the floating hose did not experience tangling as can be seen in Figure 26.

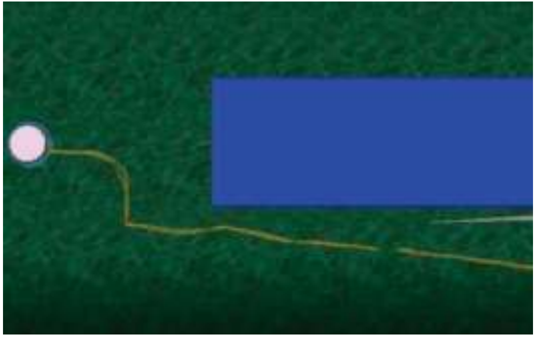

Figure 26. Collinear

6. Simulation 6

   Simulation 6 is a condition where the floating hose is not installed with a crossover but a stabilizer is installed under operating conditions (connected to the tanker). After simulation, it is found that the floating hose does not experience tangling as can be seen in Figure 27 and Figure 28.

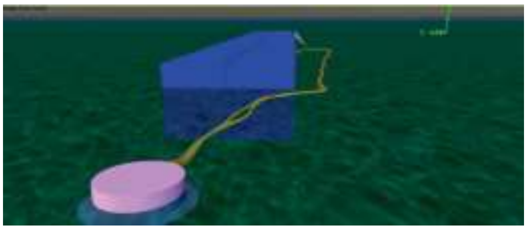

Figure 27. Collinear

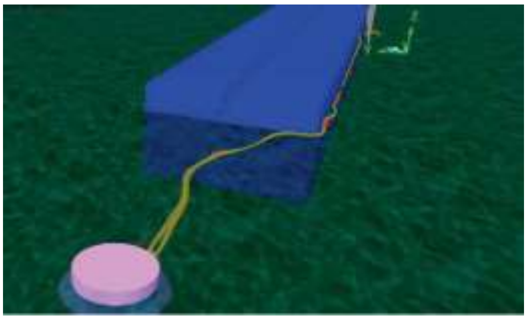

Figure 28. Non-collinear

7. Simulation 7

   Simulation 7 is a condition where the floating hose is installed with a crossover and stabilizer in operating condition (connected to the tanker). After simulation, it is found that the floating hose does not experience tangling as can be seen in Figure 29 and Figure 30.

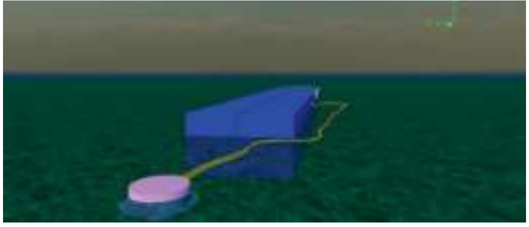

Figure 29. Collinear

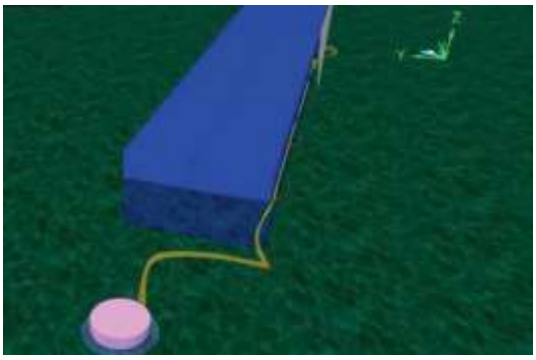

Figure 30. Non-collinear

3.3. Mooring Tension Analysis

From the data of 7 mooring tension simulations, the following analysis and recommendations are obtained:

- Tangling conditions occurred in the floating hose system without stabilizer (simulations 1-4). The installation of the planned floating hose stabilizer effectively overcomes the tangling of the floating hose as shown in simulation results 5-7.
- The mooring system stresses and maximum floating loading hoses are within allowable limits referring to ABS Single Point Mooring.
- The minimum safety factor against mooring chains during storm conditions is 6.20 above the required safety factor of 2.50 as stipulated by ABS.
- The minimum safety factor against mooring chains during operating conditions is 7.16 above the required safety factor of 3.0 as stipulated by ABS. While the minimum safety factor against the hawser during operating conditions was 4.06 above the required safety factor of 1.67.
- The maximum stress on the loading hose occurred in the first loading case (simulation 1) where the loading hose without the crossover and stabilizer was 316.11 kN. The stress on the loading hose was shown to gradually decrease in the simulation when equipped with a crossover and stabilizer simultaneously, amounting to 263.64 kN (simulation 5).
- The average stress on the stabilizer during operating conditions was 22.02 kN and 24.09 kN during storm conditions. The maximum stress on the crossover occurred during storm conditions at 40.13 kN during simulation 3. These stresses were then used to design the connection joints to resist the motion of the floating loading hoses. Adequate safety factors must be taken into account if the connection is to be used for long-term operation.
- A standby supply vessel during unloading/loading operations can be part of the backup plan to minimize entangled or twisted floating hoses.
- Based on the analysis conducted, the load that occurs when a floating hose stabilizer is used is relatively smaller than without a floating hose stabilizer. This is because when there is no floating hose stabilizer, the floating hose movement is relatively more flexible than with the floating hose stabilizer, resulting in a relatively larger pulling force.
- The amount of floating hose load on the Marine Breakaway Coupling (MBC) connection under the condition that the floating hose stabilizer is attached to the floating hose system is still smaller than the MBC load limit.

4. Conclusion

Based on the simulation results and analysis of the methodologies that have been determined, the following conclusions are obtained:

a. Tangling occurs in the floating hose condition without stabilizer.
b. The installation of floating hose stabilizer can effectively solve the tangling of floating hose.
c. With the addition of the floating hose stabilizer starting from the connection between the 5th and 6th floating hoses and at every distance of three floating hoses (connections 8-9, 11-12, 14-15 and 17-18), the tangling condition of the floating hose does not occur.
d. The maximum tension value of the mooring line both in the existing condition and after the addition of the floating hose stabilizer still meets the allowable limits referring to ABS Single Point Mooring.
e. The floating hose load value at the connection of floating hose and SPM is still smaller than the existing condition (without floating hose stabilizer).
f. The amount of floating hose load on the Marine Breakaway Coupling (MBC) connection under the condition that the floating hose stabilizer is attached to the floating hose system is still smaller than the MBC load limit.

After conducting research and analyzing the data obtained, the researchers provide suggestions that can be taken into consideration for further research and further application, including:

a. Install the floating hose stabilizer effectively and efficiently to prevent tangling that causes damage to the floating hose and losses in the form of material and environmental pollution.
b. Monitoring the mooring line tension regularly and periodically to prevent overloading the Single Point Mooring.
c. Re-study and review the relationship between variables including ocean currents, wind strength, waves and weather to get more specific results and closer to real conditions in the field.
d. Adding references and literature to expand knowledge of other variables that may need to be added to research in order to obtain optimal results.
e. Checking the floating hose stabilizer regularly to prevent failure due to corrosion due to contact with sea water.
f. Increase the application of floating hose stabilizer with different ecosystems or variables to get the efficiency level of floating hose stabilizer installation to prevent tangling.

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