An implementation of Three-Dimensional Multi-Component Mooring Line Dynamics Model for Multi-Leg mooring line configuration

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Abstract. Multi-component mooring line (MCML) system is widely used and expected to be escalated for deep water mooring operation since it has several advantages comparing with conventional mooring line. The modelling of MCML involving its dynamic effects is strongly required to predict the dynamic behaviours of the mooring line precisely. In this paper, a proposed three-dimensional dynamics model of MCML system is presented and implemented to single point multi-leg mooring line configuration operated in deep water condition. An extending three-dimensional lumped mass method is elaborated to develop the model while the combination of Manoeuvring Modelling Group (MMG) and conventional floating body motion equations is used to perform simultaneous motion between floating structure and mooring lines. The simultaneous motion is performed with respect to wind, wave, and current. The motion of the floating structure and mooring line as well as mooring line tension can be analysed properly by using the presented model. The simulation results of the model show reasonable results for both floating structure and mooring line.

1. Introduction
Floating offshore structures operated in deep water accrue with the increasing of deep water oil and gas exploitation activities. Mooring operation in deep water becomes one of the most important things to be considered. In the mooring operation in deep water, mooring line system becomes more complex and thereby several kinds of mooring line types and systems exist. Multi-component mooring line (MCML) system is widely used for deep water mooring operation since it has several advantages comparing with conventional mooring line (single-component mooring line). Ba [1] summarized the advantages of the multi-component mooring line based on two-component (polyester-chain) mooring line observed by Childers [2]. He noticed that an appropriate variation of the properties of mooring line segment (even if all segments consist of chains) can decrease the tension and increase the life of mooring line.

Since the multi-component mooring line is widely used for deep water mooring operation and it is expected to be escalated in the future, modelling of the multi-component mooring line involving the dynamic effects is strongly required. The multi-component mooring line has been involved in many studies for investigating deep water floating structure [3-9]. The multi-component mooring line itself was studied in various methods i.e. catenary method [10-12], lumped mass method [13-15], and Finite Element (FE) model [16]. Among those three models, Azcona et al. [17] reported that the lumped mass
method is most efficient comparing with the others. The lumped mass method can make the model resembles FE model, pick up necessary features only, but neglect unnecessary features in FE model.

Recently, the multi-component mooring line dynamics model developed by extending three-dimensional lumped mass method was developed by Hermawan and Furukawa [18]. The model is then extended to be used for coupled motion analysis of a floating structure [19]. The results show that the three-dimensional dynamics model gives more proper results comparing with results given by two-dimensional manner. The coupled motions of floating structure and its multi-component mooring line can be reproduced properly by using the model.

On the other hand, the motion of a floating structure moored by using single point mooring system was reported more sensitive comparing with that using other mooring system [9]. The dynamics of multi-component mooring line and lots of mooring lines on multi-leg mooring system also augment the complex calculation of multi-component mooring line implemented to multi-leg mooring system. The combination of environmental forces, water depth, and the mooring line properties may affect the performance of mooring line and hence the coupled-motion of the floating structure. Thereby, the implementation of the three-dimensional dynamics model for multi-component mooring line needs to be investigated for multi-leg mooring line configuration to verify the capability of the model for multi-leg mooring line system.

This paper performs numerical simulations of three-dimensional multi-component mooring line dynamics model applied for single-point mooring system with multi-leg mooring line configuration. The multi-component mooring line model is developed by extending three-dimensional lumped mass method presented in [19]. The simultaneous motion between a floating structure and the mooring line is gained by combining Manoeuvring Modeling Group (MMG) model and conventional floating body motion equations. Reasonable meteorological and oceanographic (metocean) data and multi-leg mooring line system consisting of multi-component mooring line type are implemented in the simulations. The simulations representing the coupled model of the mooring line and the floating structure is then used for investigating the impact of the present dynamics model of mooring line on the response of the floating structure and the tension of the mooring line itself. Moreover, external forces including wind, waves, and current are also considered in this paper.

2. Motion Equations for Floating Structure

2.1. Coordinate System

The motion equations used in this paper refer to global-fixed coordinate system as shown in figure 1 and body-fixed coordinate system figured in figure 2. $o - x_0y_0z_0$ is the global-fixed coordinate system with the origin of $z_0$-axis on water surface while $G - xyz$ is the body-fixed coordinate system with the origin at the center of gravity $G$ of a floating structure. $X$ and $Y$ represent external forces acting on the floating body in $x$ and $y$ directions while $N$ is moment around $z$-axis passing the center of gravity $G$. $V_c$, $\alpha$, $V_{u'}$, and $v$ are current velocity, current direction, wind speed, and wind direction respectively.

Forces and moments acting on the floating structure are denoted as $(X_H, Y_H, N_H)$, $(X_W, Y_W, N_W)$, $(E_3, E_5, E_4)$, $(Y_D, N_D)$, and $(X_T, Y_T, N_T)$ for hull forces including current effects, wind forces, wave exciting forces, wave drifting forces, and mooring tension forces respectively. The 6 DOF motions of the floating structure representing surge, sway, heave, roll, pitch, and yaw motions are denoted as $\ddot{x}$, $\ddot{y}$, $\ddot{z}$, $\dot{\theta}$, $\dot{\phi}$, and $\dot{\psi}$ respectively. $B_j(x_0' , y_0', z_0')$ is the attached point of the $j$-th mooring line in the body-fixed coordinate system while $\xi$ is angle between the $j$-th mooring line and $x_0$-axis. The speed of the floating structure is denoted as $U$ while its component in $x$ and $y$ directions are denoted as $u$ and $v$. Drift angle, heading angle, and yaw rate are denoted as $\phi$, $\psi$, and $\gamma$. 

\[ \frac{d}{dt} (x_0', y_0', z_0') = \dot{B}_j + \dot{U} + \ddot{B}_j x_0' + \ddot{B}_j y_0' + \ddot{B}_j z_0'. \]
2.2. External Forces

External forces acting on the body consist of hull forces, wind forces, wave forces, wave drifting forces, and tension forces. Hull forces are considered as hydrodynamic forces acting on the body given by the following expression including current effects [20],

\[
\begin{align*}
X_H, Y_H &= \frac{1}{2}\rho L d U'^* \times X'_H, Y'_H, \\
N_H &= \frac{1}{2}\rho L^2 d U'^* \times N'_H, \\
\end{align*}
\]

in which \(X'_H, Y'_H\), and \(N'_H\) are hydrodynamic forces in \(x\)- and \(y\)-directions and yaw moment respectively in non-dimensional forms. The non-dimensional hydrodynamic components are calculated by using Kijima’s model [21]. Meanwhile, \(\rho\), \(L\), \(d\), and \(U'^*\) are the density of water, length, draught, and speed of the floating structure respectively.

The formulae given by Fujiwara et al. [22] are used for approximating the wind forces acting on the floating structure. A series of wind forces and moment coefficients \(C_x(v'^*), C_f(v'^*),\) and \(C_n(v'^*)\) as the function of relative wind direction \(v'^*\) are considered to determine the wind forces. The wind forces are expressed as follow.

\[
\begin{align*}
X_W &= \frac{1}{2}\rho_A A_T U_W'^*^2 C_x(v'^*), \\
Y_W &= \frac{1}{2}\rho_A A_L U_W'^*^2 C_f(v'^*), \\
N_W &= \frac{1}{2}\rho_A A_L L_{OA} U_W'^*^2 C_n(v'^*), \\
\end{align*}
\]

with \(A_T, A_L,\) and \(L_{OA}\) are projected area in transverse and lateral views, and the length over all of the floating structure while \(\rho_A\) and \(U_W'^*\) are air density and relative wind speed respectively.

Since wave forces are generated by wave radiation and diffraction forces, wave forces must be obtained by considering both of wave radiation forces and wave exciting forces. Wave radiation forces is hydrodynamic force acting on the floating body induced by waves generated by the motion of the floating body while wave exciting force is the hydrodynamic force caused by the incident wave acting on the floating body. The wave radiation forces can be obtained by the following expression,
\[ F_{ij} = -\sum_{j=1}^{6} [(i\omega)^2 A_{ij} + i\omega B_{ij}]X_j \]
\[ = \sum_{j=1}^{6} T_{ij} X_j, \]
\[ T_{ij} = (i\omega)^2 \left\{ A_{ij} + \frac{1}{i\omega} B_{ij} \right\} \]
\[ = -\left(\frac{1}{\omega} \int L \phi_n ds\right), \]
\[ Z_{ij} = A_{ij} + \frac{1}{i\omega} B_{ij}. \]

Here, \( F_{ij} \) and \( X_j \) indicate radiation force in the \( i \)-direction due to the \( j \)-mode oscillation and a transfer function respected to the motion respectively. \( Z_{ij} \) is also the radiation force with \( A_{ij} \) and \( B_{ij} \) which represent added masses and wave damping forces respectively. The wave radiation force \( Z_{ij} \) can be obtained by determining radiation potential \( \phi_j \) over the floating body.

Furthermore, wave exciting force \( E_j \) consists of two wave force components i.e. Froude Klyrov force \( E_j^{FK} \) and diffraction force \( E_j^D \) as follows,

\[ E_j^{FK} = \rho g C_n \int L \phi_0(\xi) n_j d\xi \]
\[ = -\rho g C_n \int L e^{-ik_0\xi} \cos \mu \left\{ \int C e^{-i\kappa_0\xi - i\kappa_0 \cos \mu n_j d\xi} \right\} dx, \]
\[ E_j^D = \rho g C_n \int L \phi_D(\xi) n_j d\xi \]
\[ = -\rho g C_n \int L k_0 e^{-ik_0\xi - i\kappa_0 \cos \mu} \left\{ \int C (i \sin \mu \phi_2 - \phi_3) n_j ds \right\} dx. \]

Here, \( C, \xi, \ell \), and \( L \) indicate integral route around the circumference of hull section, line element along the circumference of hull section, and ship length respectively. \( k_0 \) is wave number of the incident wave, \( C_n \) is wave amplitude, and \( g \) represents gravitational acceleration while \( n_j \) indicates normal vector in \( j \)-direction. \( \phi_0 \) and \( \phi_D \) are velocity potential of incident wave and diffraction potential respectively. In this paper, the radiation potential \( \phi_j \), velocity potential of incident wave \( \phi_0 \), and diffraction potential \( \phi_D \) are obtained by solving boundary integral equations using New Strip Method (NSM) [23].

The second order wave forces, wave drifting force are obtained by the following expression,

\[ Y_D = \int S_H F_D dx, \]
\[ N_D = \int S_H (x - x_G) F_D dx, \]

in which \( S_H \) and \( x_G \) is a hull section and the longitudinal position of center of gravity of the floating structure.

Moreover, mooring line tension acting on the floating structure can be calculated as follow,

\[ X_T = \sum_{j=1}^{N} \left\{ T_{Hj} \cos \left( \xi_j - \psi \right) \right\}, \]
\[ Y_T = \sum_{j=1}^{N} \left\{ T_{Hj} \sin \left( \xi_j - \psi \right) \right\}, \]
\[ N_T = \sum_{j=1}^{N} \left\{ -T_{Hj} \cos \left( \xi_j - \psi \right) y_{bj} + T_{Hj} \sin \left( \xi_j - \psi \right) x_{bj} \right\}, \]

in which \( T_{Hj} \) is the horizontal tension of the \( j \)-th mooring line obtained from three-dimensional dynamics model of the mooring line.

### 2.3. Coupled Motion Equation

The motion equations of a floating structure coupled with the mooring line are given by the combination of Manoeuvring Modeling Group (MMG) model for horizontal plane motion and conventional floating body motion equations for vertical plane motion. The coupled motion equations are expressed as follows,
\[ (m + m_x)\ddot{u} - (m + m_y)\ddot{v} - (m_y - m_x)\ddot{r} + (m_y - m_x)\dot{v}_r \sin(\psi - \alpha) = X_H + X_W + X_T, \]
\[ (m + m_y)\ddot{v} + (m + m_x)\ddot{u} - (m_y - m_x)\ddot{r} + (m_y - m_x)\dot{v}_r \cos(\psi - \alpha) = Y_H + Y_W + Y_T + Y_D, \]
\[ (l_{xz} + l_{zz})\ddot{r} = N_H + N_W + N_T + Y_D. \]
\[ (M + A^G_{33})\ddot{z}(t) + B^G_{33}\dot{z}(t) + C^G_{33}z(t) + A^G_{35}\ddot{\phi}(t) + B^G_{35}\dot{\phi}(t) + C^G_{35}\phi(t) = E_{3}^{G}e^{it\omega_{3}}, \]
\[ A^G_{53}\ddot{z}(t) + B^G_{53}\dot{z}(t) + C^G_{53}z(t) + \left(I_{yy} + A^G_{55}\right)\ddot{\phi}(t) + B^G_{55}\dot{\phi}(t) + C^G_{55}\phi(t) = E_{5}^{G}e^{it\omega_{5}}, \]
\[ (I_{xx} + A^G_{44})\ddot{\theta}(t) + B^G_{44}\dot{\theta}(t) + C^G_{44}\theta(t) = E_{4}^{G}e^{it\omega_{4}}. \]

Here, \( m, m_x, \) and \( m_y \) indicate vessel mass, and its added mass components in \( x \) and \( y \) directions while \( l_{xz}, l_{yy}, \) and \( l_{zz} \) represent moment of inertia refer to \( x, y, \) and \( z \)-directions and \( l_{zz} \) is added moment of inertia. Moreover, superscript \( G \) indicates that the component forces act on the center of gravity \( G \) while \( C \) represent the restoring force coefficient of the floating structure. The motion of the floating structure and multi-component mooring line motions can be obtained simultaneously by solving these equations simultaneously as well as the dynamic motions of the mooring line.

### 3. Dynamics Model of Mooring Line

In this paper, three-dimensional lumped mass method for multi-component mooring line presented by Hermawan and Furukawa [19] is used to introduce the dynamics model of the mooring line. The model can be illustrated in figure 3 in which \( A - xyz \) is local line coordinate system with the origin of \( z \)-axis on the seabed. Here, a multi-component mooring line model is considered as the unity of several three-dimensional lumped mass models for segment line, interconnected each other and incorporated with an anchor and clump weight/buoy. The top point of the mooring line is denoted as \( P \) which means the attached point of the mooring line on the floating structure. Whilst, the bottom-end of a lowermost of segment line is denoted as \( A \) representing an anchor point.

As shown in the figure 3, a multi-component mooring line consists of \( m \) segments in which the \( i \)-th segment is divided into \( N_i \) elements while the mass of the segment line is spread out into \( N_i + 1 \) nodes. \( I - 1 \), and \( I \) refer to a touchdown point and the first lifted node while \( J_i \) is the \( i \)-th joint node. Segment length is denoted as \( L_i \) whilst the weight of the \( j \)-th node in the \( i \)-th segment is expressed as \( W_{ij} \).

![Figure 3. Three-dimensional lumped mass model of multi-component mooring line](image)

The mooring line tension \( T_{ij} \) for each segment line can be calculated by the following expression,

\[ T_{ij}^{n+1} = T_{ij}^{n+1} + \Delta T_{ij}^{n+1} \quad (j = 1 \sim N). \]

The unknown parameter \( \Delta T_{ij} \) can be obtained by solving the simultaneous equations derived as follow,
properties is defined based on the properties commonly used for Indonesian sea. Moreover, the Administration (NOAA) referring to Masela field as the consid-
ted location. The mooring line properties is defined based on the properties commonly used for Indonesian sea. Moreover, the

\[ \begin{bmatrix}
-\tilde{E}_{i2}^{n+1} & \tilde{G}_{i2}^{n+1} & 0 & 0 & \cdots & 0 & 0 & 0 \\
\tilde{E}_{i3}^{n+1} & -\tilde{F}_{i3}^{n+1} & \tilde{G}_{i3}^{n+1} & 0 & \cdots & 0 & 0 & 0 \\
0 & \tilde{E}_{i4}^{n+1} & -\tilde{F}_{i4}^{n+1} & \tilde{G}_{i4}^{n+1} & \cdots & 0 & 0 & 0 \\
\vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\
0 & 0 & 0 & \cdots & \tilde{E}_{iN}^{n+1} & -\tilde{F}_{iN}^{n+1} & \tilde{G}_{iN}^{n+1} & 0 \\
0 & 0 & 0 & \cdots & \tilde{E}_{iN+1}^{n+1} & -\tilde{F}_{iN+1}^{n+1} & \tilde{G}_{iN+1}^{n+1} & \tilde{l}_{iN}^{n+1}
\end{bmatrix}
\begin{bmatrix}
\Delta T_{i1}^{n+1} \\
\Delta T_{i2}^{n+1} \\
\Delta T_{i3}^{n+1} \\
\vdots \\
\Delta T_{iN}^{n+1} \\
\Delta T_{iN+1}^{n+1}
\end{bmatrix}
= 
\begin{bmatrix}
-\tilde{Y}_{i2}^{n+1} \\
-\tilde{Y}_{i3}^{n+1} \\
-\tilde{Y}_{i4}^{n+1} \\
\vdots \\
-\tilde{Y}_{iN}^{n+1} \\
-\tilde{Y}_{iN+1}^{n+1}
\end{bmatrix}, \tag{10}
\end{equation}

in which the respective coefficient $\tilde{E}_{ij}$, $\tilde{F}_{ij}$, and $\tilde{G}_{ij}$ can be observed in Nakajima et. al [24]. The following expression must be zero to satisfy the constraint condition of equation (10),

\[ \tilde{Y}_{ij}^{n+1} = (\tilde{x}_{ij}^{n+1} - \tilde{x}_{ij+1}^{n+1})^2 + (\tilde{y}_{ij}^{n+1} - \tilde{y}_{ij+1}^{n+1})^2 + (\tilde{z}_{ij}^{n+1} - \tilde{z}_{ij+1}^{n+1})^2 - \tilde{l}_{ij}^2 (1 + T_{ij+1}^{n+1}/E_i \cdot A_i)^2. \tag{11} \]

The segment line tension and its motion can be obtained by solving equation (10) iteratively until $\Delta T_{ij}$ converges. By calculating each segment continuously, the motion of the multi-component mooring line can be obtained. The detail numerical calculation model of the multi-component mooring line can be referred in Hermawan and Furukawa [19].

4. Simulation Results
4.1. Calculation Conditions
In order to verify the capability of three-dimensional dynamics model for multi-component mooring line applied for multi-leg mooring line configuration, simulations using the model for single-point mooring system on multi-leg mooring line configuration are conducted. In the simulations, a ship-type floating structure is moored by single point multi-leg mooring configuration and spread out into three groups. Every group are spread off by 120° and consists of three identical multi-component mooring line deployed by 10° each other. The schematic view of the mooring line configuration is shown in figure 4.

![Figure 4. Mooring line arrangement for the simulation](image)

The floating structure used in these simulations refers a VLCC (ESSO OSAKA) which is assumed to be as a ship-type floating structure. Metocean data is taken from National Oceanic and Atmospheric Administration (NOAA) referring to Masela field as the considered location. The mooring line properties is defined based on the properties commonly used for Indonesian sea. Moreover, the
simulations are conducted for two conditions of external forces directions against the mooring line i.e. in-between mooring line and in-line mooring line condition. The direction of the external forces for in-between line condition is 60° while the in-line condition is 120° respect to the initial heading of the floating structure. The principle dimensions of the floating structure as well as the properties of the mooring line and metocean data are shown in table 1 and table 2 respectively while the considered location and the schematic view for in-line and in-between mooring line condition are figured in figure 5 and figure 6.

**Table 1.** Principle dimensions of the floating structure and the mooring line properties for simulations.

| Ship-type floating structure | Mooring line properties |
|-----------------------------|-------------------------|
|                            | Notation | Segment 1 | Segment 2 | Segment 3 |
| $L_{DA}$ (m)               | 343.00   | 660.00    | 1595.00   | 220.00    |
| $L_{PP}$ (m)               | 325.00   | 322.93    | 210.16    | 299.80    |
| $B$ (m)                    | 53.00    | 127.00    | 102.00    | 117.00    |
| $d$ (m)                    | 22.05    | $4.89 \times 10^9$ | $1.03 \times 10^9$ | $2.15 \times 10^9$ |
| $C_b$                      | 0.831    | 17250.00  | $T_{Preten}$ (N) | 22000.00  |

| Type                        | Chain    | Chain    | Chain    |
|------------------------------|----------|----------|----------|

**Table 2.** Metocean data used for the simulations.

| Parameter                      | Value                              |
|--------------------------------|------------------------------------|
| Water depth                    | 783 m                              |
| Wave height (100-years)        | $4.9612$ m ($H_p$)                 |
| Wave period (100-years)        | $17.1268$ sec. ($T_p$)             |
| Wind speed (100-years)         | $21.2426$ m/sec. (10 m above sea level in 1-hour mean wind) |
| Current speed (10-years)       | $1.10$ m/s $= 2.1382$ knots        |

**Figure 5.** Masela field location used for the simulations
4.2. In-between Mooring Line Condition

To investigate the effect of direction of external disturbances relative to the arrangement of mooring lines, external disturbances coming from the direction between two line groups are considered in present case. Here, external disturbances which come from the direction between Group Line (GL) I and GL II are applied for the collinear condition whilst all external disturbances come from 60° relative to the bow.

Figure 7 shows the trajectory of the ship-type floating structure during the simulations with the time histories of horizontal forces for this case. According to the figure, it can be found that the mooring lines can move simultaneously interrelating each other following the external disturbances. The motions of the floating structure show the reasonable results. The final heading of the floating structure corresponds to the directions of the external disturbances. The heading of the floating structure has the same direction which is close to external disturbances direction. However, lateral force and yawing moment are observed at the beginning of the simulation since the external disturbances force the floating structure to turn around its bow position. Then, the floating structure will be placed in beam sea or bow sea condition at the beginning of the simulation. The lateral force and yawing moment vanish when the heading of the floating structure is in-line with the direction of external disturbances. Finally, external forces come from the direction between GL I and GL II. In other words, the direction is exactly in-line with GL III. The tension of GL I and GL II become bigger whilst that of GL III hardly change.

Figure 6. In-between and In-line condition used for the simulations

Figure 7. Trajectories and horizontal forces for in-between condition
The motions of the floating structure for in-between line condition can be evaluated in figure 8. It can be found that the tendency of the motions is confirmed with the heading and the trajectories of the floating structure shown in figure 7. The displacement of floating structure position as well as the heading angle shown in figure 8 are confirmed with the trajectories in figure 7.

Furthermore, mooring line tension affected by the coupled motions is presented in figure 9. From the figure, because all external disturbances in the collinear condition come from the direction between GL I and GL II, environmental loads which are restrained by mooring lines are distributed to the both line groups. In conforms to the tension shown in the figure where the maximum tension in the collinear condition occurs in both of GL I and GL II (lines 1, 3, 4, and 6).

4.3. In-line Mooring Line Condition
To consider the other condition of external disturbances, analysis of the floating structure coupled with mooring lines under in-line condition is investigated. In this condition, all external disturbances in the collinear condition come from the direction which is in-line with GL II (120°). The trajectories of the ship-type floating structure are presented in figure 10. According to the figure, the shapes of the floating structure show similar results concerning to the directions of external disturbances. The floating structure moves following the direction of external disturbances which is in-line with GL II.
In consequences, the mooring lines in GL II tend to move to the same direction with external disturbances while the mooring lines in GL I and GL III tend to move toward negative direction of $y_0$ axis. This condition is different from that in the non-linear condition in which the total environmental loads force the floating structure to move toward GL I. Thus, the floating structure rotate around its bow until its heading angle reaches the opposite direction.

The motions of the floating structure delineated in figure 11 indicate the same tendency for in-between case concerning to how floating structure move following the direction of external forces. For this case, even though the floating structure experiences larger vertical motions when dealing with the external force at the beginning of the simulation, the floating structure then turn around following the direction of external forces and finally the heading of the floating structure is in opposite direction of the external forces direction.

Furthermore, as shown in figure 12, the maximum tension for this in-line condition occurs in mooring lines in GL II i.e. mooring lines 4, 5, and 6. Because GL II is in-line with the all of external disturbances and environmental loads concentrated on the GL, GL II should withstand these loads. In consequence, the mooring line in GL II must withstand environmental loads almost singly. Thereby, the mooring line results show the reasonable results.
5. Conclusions
Three-dimensional dynamics model of multi-component mooring line applied for multi-leg mooring line has been presented. The three-dimensional dynamics model for multi-component mooring line has been presented based on the extending lumped-mass model. The coupled motion between floating structure and the mooring line is figured by the combination of MMG model and conventional floating body motion. The analyses are conducted under in-between line and in-line conditions of external disturbances. According to the analysis, the external forces and mooring line properties data are based on the reasonable metocean and mooring line properties data.

In this paper, two cases of external forces directions relative to mooring line configuration are investigated. The coupled motion of the floating structure and multi-component mooring line can figure the simultaneous motion between them properly even for single point multi-leg mooring line configuration. According to the results, the three-dimensional mooring line model can reproduce the tension as well as motion of mooring line even for multi-line conditions since the mooring line moves with the floating structure simultaneously.

In addition, the results generally show that the proposed dynamics model is considered to be an adequate model for representing dynamic behavior of a multi-component mooring line since the coupling of the model with the floating structure provides appropriate relations between them as well as against the environmental conditions. Therefore, confirming the results, the proposed coupled dynamics model of a multi-component mooring line is capable to be applied for the analyses of the motion of a floating structure even for single-point multi-leg mooring configuration. It also capable for investigating the coupled dynamic motions and mooring line tension for dealing with the measured metocean data at a certain target location. In further, it also can provide the motion of a multi-component mooring line in three-dimensional manner.

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