THESIS – MO142528

PARAMETRIC STUDY OF FATIGUE ANALYSIS ON EXTERNAL TURRET MOORING LINE

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PARAMETRIC STUDY OF FATIGUE ANALYSIS ON EXTERNAL TURRET MOORING LINE

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ABSTRACT

This thesis presents the parametric study of fatigue life applied on turret-moored Floating LNG. Several parametrical cases were designed to investigate the influence of mooring line pretension, water depth and wave load component (1^{st} order and 2^{nd} order wave load) on the fatigue life of turret mooring systems. The object is Floating LNG with permanent external turret mooring operated in 602m water depth. The mooring system consists of 12 catenary lines arranged in 3 group with 4 lines of each. Time domain simulation applied to calculated coupled dynamic response and mooring lines tension. Fatigue life assessed using rainflow counting method, T-N curves and Palmgren-Miner rule.

Analysis results for mooring pretension show that case study 2 with lowest pretension (14%MBL) yields shortest mooring fatigue life of 1814.20 years compared to case study 1 (18%MBL) and case study 3 (22%MBL) with 2034.61 years and 2983.33 years respectively. Despite has the lowest dynamic line tension, case study 2 has larger tension range that results in the increased of fatigue damage. The increase in water depth will increase mooring line length, weight and so it results in the increased of fatigue damage. This is reflected in case study 5 (903m water depth), which has shortest mooring fatigue life of 1842.65 years compare to case study 1 (602m water depth) and case study 4 (301m water depth) with 2983.33 years and 3363.62 years respectively. For the case of wave load type, 1^{st} order wave component yields shorter mooring fatigue life of 1186.71 years compared to 2^{nd} order wave component with mooring fatigue life of 2872.47 years. Although the 1^{st} order wave component has less effect in global motion response and line tension on moored vessel, its induced higher fatigue damage than 2^{nd} order wave component.

Keywords: External turret, Fatigue life, Mooring lines, Pretension, Water depth, Wave load

PREFACE

Assalamu'alaikum Wr. Wb.

Praise to Allah SWT for the gracious mercy and tremendous blessing that enables the author to accomplish the thesis entitled, "Parametric Study of Fatigue Analysis on External Turret Mooring Line". This thesis is carried out for the completion of master degree program of Design of Ocean Structures Engineering, Ocean Engineering Department, Faculty of Marine Technology at Sepuluh Nopember Institute of Technology (ITS) Surabaya. This thesis generally discussed the influence of several parameters on fatigue life design of mooring lines. Floating LNG with external turret mooring system are selected object in this study.

The author would like to thank everyone for the help and support during the work of this thesis. At the moment, author would address huge thanks and appreciation for:

1. My parents, Mr. Sudarmoro (Alm.) and Mrs. Mahmoedah Sjoehadminingsih for the endless support, timeless pray and unconditional love. My brother, Augene, and sister, Medina for the constant support.
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Learning about hydrodynamic and mooring analysis related to this thesis has been challenging, yet very useful to the author on understanding the fatigue life design on mooring line. The author acknowledges that this thesis is not perfect, advice and suggestion are most welcome for further work. Hopefully, this thesis can be useful for the readers.

Surabaya, July 2018

Author
Norman Mahdar Sabana

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NOMENCLATURE

A_L	=	lateral projected wind area (m^2)
ALS	=	lateral projected current area (m^2)
A_T	=	transverse projected wind area (m^2)
ATS	=	transverse projected current area (m^2)
$A(\omega)$	=	frequency-dependent added mass matrix
B	=	breadth of the ship (m)
$C(\omega)$	=	frequency-dependent potential damping matrix
$C_{*w}(\alpha_{rw})$	=	α_{rw} - dependent wind load coefficient (-)
$C\text{-}C(\alpha c)$	=	αc - dependent current load coefficient (-)
D_i	=	annual fatigue damage to the component due to environmental state i
D_1	=	linear damping matrix
D_2	=	quadratic damping matrix
E	=	elastic modulus
$E[R_i^M]$	=	expected value of the normalized tension range Ri raised to the power M, in state i
$f(\dot{x})$	=	vector function where each element is given by $\dot{x}_i\lvert\dot{x}_i\rvert$
Hs	=	significant wave height
$K(x)$	=	position-dependent stiffness matrix
L	=	length of the ship (m)
L_m	=	ratio of mean load to reference breaking strength (RBS) for wire rope
m	=	body mass matrix
N	=	number of cycles
Nc	=	steady horizontal current moment (Nm)
N_w	=	steady horizontal wind moment (Nm)
n_i	=	the number of tension cycles encountered in state i per year
q_{CU}	=	current drag force
q_{oth}	=	other forces including forces from the mooring system

q_{WI} = wind drag force

q_{WA}^{1} = first order wave excitation force

q_{WA}^{2} = second order wave excitation force

$q(t, x, \dot{x})$ = excitation force vector

R = ratio of tension range (double amplitude) to reference breaking strength (RBS)

Rn = Reynolds number (-)

$R(\omega_i)$ = reflection coefficient (=1.0)

S = wetted surface of the ship (m^2)

s = catenary length

T = draft of the ship (m)

Tp = wave peak period

T_H = horizontal component of tension

T_z = vertical component of line tension at the top end

t = time variable

Vc = relative current velocity (m/s)

V_{rw} = relative wind velocity (m/s)

v = kinematic viscosity of water (m^2s)

X_c = steady longitudinal current force (N)

X_w = steady longitudinal wind force (N)

$x, \dot{x}, \ddot{x}$ = vectors of displacement, velocity and acceleration

Yc = steady lateral current force (N)

Y_w = steady lateral wind force (N)

αc = relative current direction (-), from astern is zero

α_w = relative wind direction (-), from astern is zero

ρ = density of water (kg/m^3)

ρ_{air} = density of air (kg/m^3)

$\emptyset_{\text{initial}}$ = initial diameter of mooring line

$\emptyset_{\text{corroded}}$ = corroded diameter of mooring line

ω = frequency of incident waves

ABBREVIATIONS

ABS	=	American Bureau of Shipping
API	=	American Petroleum Institute
CCW	=	Counter-Clockwise
DNV-OS	=	Det Norske Veritas – Offshore Standard
DOF	=	Degree of Freedom
EFCS	=	Earth-Fixed Coordinate System
FD	=	Frequency Domain
FLNG	=	Floating Liquified Natural Gas
FoS	=	Factor of Safety
FP	=	Fore Perpendicular
FPSO	=	Floating Production Storage and Offloading
FPU	=	Floating Production Unit
ITTC	=	International Towing Tank Conference
KMl	=	Keel to Metacentre Longitudinal
KMt	=	Keel to Metacentre Transversal
LCB	=	Longitudinal Centre of Buoyancy
LCF	=	Longitudinal Centre of Floatation
LF	=	Low-Frequency
MBL	=	Minimum Breaking Load
MBS	=	Minimum Breaking Strength
MODU	=	Mobile Offshore Drilling Unit
NPD	=	Norwegian Petroleum Directorate
QTF	=	Quadratic Transfer Function
RAO	=	Response Amplitude Operator
RBS	=	Reference Breaking Strength
SPM	=	Single Point Mooring
STD	=	Standard Deviation
TCB	=	Transverse Centre of Buoyancy
TD	=	Time Domain

TLP	=	Tension Leg Platform
VCB	=	Vertical Centre of Buoyancy
VCG	=	Vertical Centre of Gravity
VFCS	=	Vessel-Fixed Coordinate System
WD	=	Water Depth
WF	=	Wave-Frequency

1. INTRODUCTION

1.1 Background

Floating structures are extensively used for oil and gas production at sea. The number of floating structures operating in the world increased substantially during the 1990's. As of November 2013, the inventory of Floating Production Units (FPUs) stands at 277 around the world, which 62% of the total are FPSOs (Offshore, 2013b). Under environmental loads of waves, wind and current, a free-floating structure experience offsets different from desired operation point. Such structures are commonly moored to the sea bed. Mooring system consist of chains, cables, ropes and anchors which connected between seabed and structure. Mooring lines are still the most important and economically effective components for station-keeping under environmental loads. Mooring systems must provide such station keeping capability and high global performance to ensure allowable excursions against environmental loads.

First Single Point Mooring (SPM) was installed in the Arabian Gulf in 1964, since then, a number of these units are now in use. A typical early facility consisted of a buoy that serves as a mooring terminal. It is attached to the sea floor either by catenary lines, taut mooring lines or a rigid column. The vessel is moored to the buoy either by synthetic hawsers or by a rigid A-frame yoke. Turntable and fluid swivels on the buoy allow the vessel to weathervane, reducing the mooring loads. Even though has several good design features, the SPM system involves many complex components and is subjected to a number of limitations. More recently, turret mooring systems for monohull floating production and storage vessels have been developed that are considered to be more economic and reliable than SPMs, and are widely used today. The turret can either be external or internal. Mooring lines connect the turret to the seabed (Brown, 2005).

What makes a turret moored system special is that the vessel can rotate around the fixed turret. The vessel can then position itself in such a way that it minimizes the forces acting on the vessel from the environment by reducing the total exposed surface. It is also easier to keep the desired position with such systems. Fewer chains and smaller anchors can then be used compared to a traditionally spread mooring system. This is one of the main advantages with a turret moored system. Figure 1-1 shows Floating Production Unit equipped with external turret mooring on the bow.

Figure 1-1 Floating Production Unit with external turret mooring (Wall, 2002)

When a vessel is exposed to waves, it experiences wave loads that can be split into first order and second order terms. The first order terms generate motion at wave frequency, while the second order terms are much smaller but they include loads with a much lower frequency. These low frequency terms are called the wave drift loads and they can cause significant slow drift motions of the vessel if their frequencies are close to a natural frequency of the vessel. Ormberg and Larsen (1998) studied a turret-moored FPSO operating in different water depth, showed that for large water depth, the low frequency response becomes dominant and non-coupled analysis failed to predict the motions accurately.

Variance in wind, current, and wave loads generate variable motion and tension in the mooring system. Unlike trading ships, Floating Production Unit stay at the same location year after year without regular dry docking for inspection and repair. Since the FPU cannot move off the station, then she must withstand whatever weather comes their way. Gradual accumulation of the variable tension in the mooring line can lead to cumulative fatigue damage. Between 2001 and 2011, mooring incidents have been occurring at a high rate. More than twenty (20) incidents have happened to production vessels that are moored on-site for prolonged duration (typically 15-25 years). Among those, at least eight (8) had multiple line damages, or system failure. Some of them led to vessel drifting (Ma et al., 2013). Assessing the fatigue life of mooring systems attract industry attention and becomes important in the offshore industry.

Table 1-1 Major mooring incidents between 2001 and 2011 (Ma et al., 2013)

Year	Vessel Name	Incident
2011	Banff	5 of 10 lines parted
2011	Volve	2 of 9 lines parted, no damage to riser
2011	Gryphon Alpha	4 of 8 lines parted, vessel drifted a distance, riser broken
2010	Jubarte	3 lines parted between 2008 and 2010
2009	Nan Hai Fa Xian	4 of 8 lines parted, vessel drifted a distance, riser broken
2009	Hai Yang Shi You	Entire yoke mooring column collapsed; vessel adrift, riser broken
2006	Liuhua (N.H.S.L)	7 of 10 lines parted, vessel drifted a distance, riser broken
2002	Girassol Buoy	3 of 9 lines parted, no damage to offloading lines.

This master thesis conduct fatigue analysis on the mooring lines of a Floating LNG with external turret mooring system. The analysis emphasizes the influence of several parameters on fatigue life of mooring lines. The influence of mooring line pretension on the fatigue life of lines will be calculated and compared. Fatigue life analysis will be conducted for several pretension values and the results will be compared each other.

The modelled moored vessel will also be simulated in several values of water depth to investigate its effect on fatigue life mooring lines. The influence of 1st order and 2nd order wave load on the fatigue life of mooring lines will also be investigated. The various results obtained from these studies can be used as reference for fatigue analysis of mooring lines with external turret system.

1.2 Problem Definitions

This master thesis will cover following problems to be discussed:

1. The influence of mooring line pretension on the fatigue life of external turret mooring lines.
2. The influence of water depth on the fatigue life of external turret mooring lines.
3. The influence of wave load (1^{st} order and 2^{nd} order) on the fatigue life of external turret mooring lines.

1.3 Research Objective

The objective of this research are as follows:

1. Identify the influence of mooring line pretension on the fatigue life of external turret mooring lines.
2. Identify the influence of water depth on the fatigue life of external turret mooring lines.
3. Identify the influence of 1^{st} order and 2^{nd} order wave load on the fatigue life of external turret mooring lines.

1.4 Research Scope

Scope of research for this master thesis are defined as follows:

1. Floating structure assumed as a rigid body, no deformation occurred under certain loads.
2. Floating structure studied in these research is Floating LNG with external turret mooring system.
3. Environmental loads of wind, current and wave (1^{st} order and 2^{nd} order) are considered in the analysis.
4. Tidal conditions are neglected and operational draft measured at mean sea level (MSL).
5. Seabed profile assumed to be flat.

6. Risers and umbilical are not accounted in the analysis.
7. Mooring connection elements/links are not accounted in the analysis.
8. Dynamic simulation performed using time domain coupled analysis.
9. Fatigue damage are calculated based on effective tension of mooring lines (Tension-Tension Fatigue).

1.5 Report Format

This report starts with introduction on the Section 1. This section covers research background, problem definition, research objective and scope of work applied in this research.

Literature study and theoretical background is described in Section 2. This section covered reference and theory used as guidance for this master thesis. Reference could be taken from journals, books, rules and codes relevant with subject of this research.

Section 3 describes research methodology, covers the method and step used to performed the research. Data identification, structure modelling and model verification were discussed in this section.

Section 4 describes results obtained from the analysis. The results obtained from analysis will be processed to give brief understanding related to the subject. Based on the results, a conclusion will be drawn in the Section 5. Recommendations for the future research will also be given in this section.

2. LITERATURE STUDY AND THEORETICAL BACKGROUND

2.1 Literature Study

During the past years, the requirements to the mooring and station keeping systems of mobile and permanent units have become more complex. The industry is moving into new frontiers (ultra-deep water), also the new floating units are becoming larger and many units are at the end of their lifetime. In addition, mooring failure rate is unacceptably high. Some incidents have been multiple line failures, leading to vessel drifting. The investigations show a variety of direct causes covering both inaccurate design, bad quality in fabrication of mooring line components and insufficient fatigue resistance of components, in particular the mooring line component.

Ormberg and Larsen (1998) studied coupled analysis of floater motion and mooring dynamics of a turret-moored ship. Turret motions and line tensions from experiments, traditional separated analysis and coupled analysis are compared. The turret motions estimated by a separated analysis compare well with both coupled and experiments. However, for both line tension and turret forces, separated approach gives underpredicted results compared to coupled analysis. The underprediction is especially the case for vertical turret forces and this trend increases with increasing water depth. In deep water, a coupled analysis approach is therefore highly recommended for checks of important design cases.

Lin and Sayer (2015) studies two type of mooring system design method (coupled Low frequency and fully coupled) and assessed the behavior of mooring system in different water depth. Both mooring line tension and surge response are completely determined by the Low frequency (LF) response, particularly for large water depths. The Wave frequency (WF) surge response is independent of water depth, in contrast to the LF surge response. Water depth variation has little effect on mean heave motion, even at resonance. For a catenary chain, the WF response becomes more significant as the water depth increases. However, for a taut mooring line, the WF response is significant in intermediate water depths (between 1500m and 2000m), becoming less important in ultra-deep depths(>2000m).

Han et al. (2010) studied the different composition of mooring system and its effect on the fatigue life of mooring lines. They compare the extreme dynamic loads and fatigue life performance of different configuration of mooring system (4x4 and 4x3) which has similar static stiffness. A time-domain computational is used to determine the extreme tension, while the spectral method is implemented for estimating the fatigue life. The maximum tension in 4x3 mooring system is about 26% higher than that in 4x4 system. The maximum offset is almost same. The fatigue life of two systems turns out to be similar, which the upper chain has the shortest fatigue life.

Chrolenko (2013) compare results for mooring lines analyses in Frequency Domain (FD) and Time Domain (TD) for turret moored FPSO at particular water depth. The comparison will be to investigate differences in response calculations for leeward lines, for the purpose of estimating fatigue damage in a given short-term sea state. For fatigue damage the most important parameters are the standard deviation (STD) of low- and wave-frequency tension (LF and WF).

Wu et al. (2014) presented numerical analysis of fatigue damage along mooring lines for semi-submersible in the deepwater. They identify the most critical fatigue damage locations for different mooring systems. The factors affecting the critical location, such as: mooring pattern, pretensions, chain length, water depth are discussed, thus provides recommendations for mooring fatigue design of offshore structures.

Saidee (2015) presented fatigue design of spread mooring component for different analysis method as per DNV-OS-E301. Comparative study shows that RFC method will predict higher fatigue damage compare to other methods. It is also recommended to do Time domain analysis to be sure about fatigue damage since only doing Frequency domain analysis might under predicts the fatigue damage that leading to failure of the mooring lines in future.

Kang et al. (2016) studied fatigue analysis of spread mooring line. Contribution of environmental loads (wind, wave, current), type of responses (WF and LF motions), vessel offsets, mooring position, loading conditions (ballast, intermediate, full) and riser behavior (with and without riser) are investigated. Fatigue analysis performed through dynamic time domain simulation, while number of cycles of tension is calculated using rain-flow counting method.

Junfeng et al. (2016) studies the effect of several factors on Low frequency (LF) fatigue damage of mooring lines applied in a Semi-Submersible platform. Analytical cases designed to perform fatigue analysis to investigate the influence of water depth, Hs, Tp and riser system on the fatigue damage of mooring systems. The platform system in deeper water has smaller mooring stiffness and higher damping ratio, which results in a larger system natural period. For the mooring line tension and fatigue damage, the WF components increase with the increase of water depth, but the LF components decrease due to higher damping.

This thesis deals with several parameters that might affect the fatigue performance of mooring lines. The external turret mooring system of FLNG is chosen in this study. It has chain and wire components from fairlead to anchor. The studied parameters for sensitivity are mooring line pretension, water depth and wave loads type. In order to perform fatigue analysis, time series of tension mooring lines were calculated through dynamic analysis. Fatigue life of mooring lines were obtained using Rainflow counting method, T-N curve and the Miner's linear cumulative law model which is the common used method for fatigue damage calculation.

2.2 Theoretical Background

2.2.1 Rigid Body Motions

The rigid-body translational motions are referred to as surge, sway and heave, while the rotational motions are referred to as roll, pitch and yaw. For a ship-shaped structure, surge is the longitudinal motion and roll is the angular motion about the longitudinal axis. All six rigid-body motions can be seen in Figure 2-1.

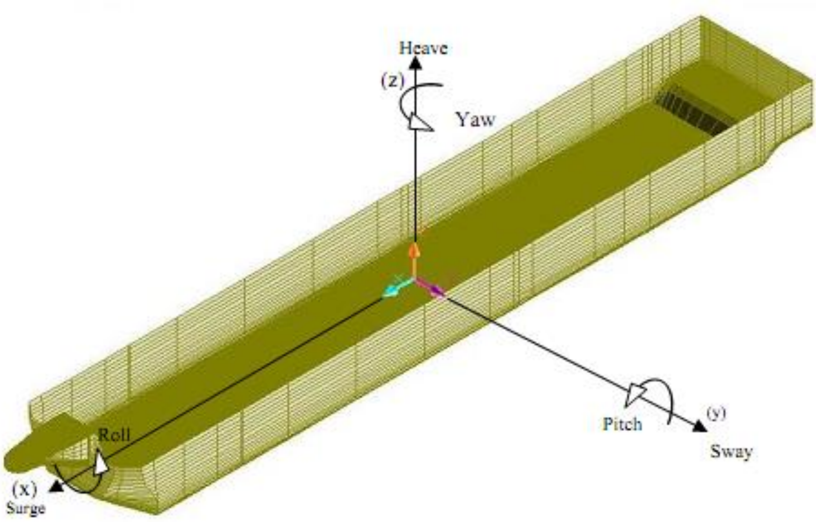

Figure 2-1 Floating body motion modes (Mahdarreza, 2011)

Motions of floating structures can be divided into static and dynamic motion. Static motion is the mean offset, whereas dynamic motion can be divided by frequency-content into:

- Wave-frequency motion: linearly-excited motion in the wave-frequency range of significant wave energy. This is the ordinary seakeeping motion of a vessel. It may be calculated using the first-order motion theory.
- High-frequency motion: motion with period substantially below the wave period. For ocean-going ships, high frequency springing forces arise producing a high-frequency structural vibration that is termed whipping (Bhattacharyya, 1978). For floating production structure, this motion is significant for TLP which have high axial stiffness of tethers, referred to as

"ringing" and "springing" and is due to resonance oscillation in heave, pitch and roll of the platform. The natural periods of these motion modes are typically 2-4 seconds which are less than most wave periods. They are excited by non-linear wave effects, where "ringing" is associated with transient effect and "springing" is steady-state oscillations.

- Slow-drift motion and mean drift: motion with period in the range of 100-200 seconds. Slow-drift motion arises from resonance oscillations. For a moored structure, it occurs in surge, sway and yaw. The restoring force are due to the mooring system and the mass forces due to the structure. The slowly-varying response is of equal importance as the linear first-order motions in design of mooring and riser systems. Wind will also induce slow-drift and mean motion of marine structures with high natural periods. This is caused by wind gusts with significant energy at periods of the order of magnitude of a minute.

Mean offset of the floating vessel is determined at an equilibrium position under the combined mean forces of waves (mean wave drift), wind and current by considering the nonlinear restoring forces of the mooring system. Dynamic motions are established at the equilibrium position of the vessel.

The equation of motions for the vessel in regular waves may be written as:

$$M\ddot{x} + C\dot{x} + D_1\dot{x} + D_2 f(\dot{x}) + K(x)x = q(t, x, \dot{x}) \tag{2.1}$$

$$\mathrm{M} = m + A$$

$$A = A(\omega) = A(\infty) + a(\omega)$$

$$C = C(\omega) = C(\infty) + c(\omega) = c(\omega)$$

where:

t	=	time variable
ω	=	frequency of incident waves
$x, \dot{x}, \ddot{x}$	=	vectors of displacement, velocity and acceleration
m	=	body mass matrix
A(ω)	=	frequency-dependent added mass matrix
C(ω)	=	frequency-dependent potential damping matrix

D_1 = linear damping matrix

D_2 = quadratic damping matrix

$K(x)$ = position-dependent stiffness matrix

$f(\dot{x})$ = vector function where each element is given by $\dot{x}_i|\dot{x}_i|$

$q(t, x, \dot{x})$ = excitation force vector

The excitation force on the right-hand side of Equation (2.1) includes the following components:

$$q(t, x, \dot{x}) = q_{WI} + q_{WA}^1 + q_{WA}^2 + q_{CU} + q_{oth} \tag{2.2}$$

where:

q_{WI} = wind drag force

q_{WA}^1 = first order wave excitation force

q_{WA}^2 = second order wave excitation force

q_{CU} = current drag force

q_{oth} = other forces including forces from the mooring system

2.2.2 Wind Loads

Wind loading is important for prediction of global motion response of floaters. Accurate modelling of the wind effects is therefore essential. For some floating systems, the wind loads can be the dominating the excitation.

Similar with all environmental phenomena, wind has a stochastic nature which greatly depends on time and location. It is usually characterized by large fluctuations in velocity and direction. It is common meteorological practice to give the wind velocity in terms of the average over a certain interval of time, varying from 1 to 60 minutes or more. Local winds are generally defined in terms of the average velocity and average direction at a standard height of 10 meters above the still water level. A number of empirical and theoretical formulas are available in the literature to determine the wind velocity at other elevations. An adequate vertical distribution of the true wind speed z meters above sea level is represented by:

$$\frac{V_{tw}(Z)}{V_{tw}(10)} = (\frac{Z}{10})^{0.11} \tag{2.3}$$

in which:

V_{tw}(z) = true wind speed at z meter height above the water surface

V_{tw}(10)= true wind speed at 10 meters height above the water surface

Equation (2.3) is for sea conditions and results from the fact that the sea is surprisingly smooth from an aerodynamic point of view - about like a well mowed soccer field. On land, Equation (2.3) has a different exponent:

$$\frac{V_{tw}(Z)}{V_{tw}(10)} = (\frac{Z}{10})^{0.16} \tag{2.4}$$

At sea, the variation in the mean wind velocity is small compared to the wave period. The fluctuations around the mean wind speed will impose dynamic forces on an offshore structure, but in general these aerodynamic forces may be neglected in comparison with the hydrodynamic forces, when considering the structures dynamic behavior. The wind will be considered as steady, both in magnitude and direction, resulting in constant forces and a constant moment on a fixed floating or a sailing body.

Wind loads acting in floating structures plays two roles as below:

a) Direct role, where the wind exerts a force on the part of the structure exposed to the air. Wind forces are exerted due to the flow of air around the various parts. Only local winds are needed for the determination of these forces.
b) Indirect role, where winds generate waves and currents and through these influence a ship indirectly too. This is a fluctuating component due to wind gust which mainly excite the low frequency motions in surge, sway and yaw. The effects of waves and currents on floating bodies will be dealt with separately in later chapters.

Only the direct influence of the winds will be discussed here. Forces and moments will be caused by the speed of the wind relative to the (moving) body. The forces and moments which the wind exerts on a structure can therefore be computed by:

$$X_w = \frac{1}{2}\rho_{air}V_{rw}^2 . C_{Xw}(\alpha_{rw}). A_T \tag{2.5}$$

$$Y_w = \frac{1}{2}\rho_{air}V_{rw}^2 . C_{Yw}(\alpha_{rw}). A_L \tag{2.6}$$

$$N_w = \frac{1}{2}\rho_{air}V_{rw}^2 . C_{Nw}(\alpha_{rw}). A_L . L \tag{2.7}$$

in which:

X_w	=	steady longitudinal wind force (N)
Y_w	=	steady lateral wind force (N)
N_w	=	steady horizontal wind moment (Nm)
$\rho_{air} \approx \rho_{water}/800$	=	density of air (kg/m^3)
V_{rw}	=	relative wind velocity (m/s)
α_w	=	relative wind direction (-), from astern is zero
A_T	=	transverse projected wind area (m^2)
A_L	=	lateral projected wind area (m^2)
L	=	length of the ship (m)
$C_{*w}(\alpha_{rw})$	=	α_{rw} - dependent wind load coefficient (-)

Note that it is a normal convention to refer to the true wind direction as the direction from which the wind comes. A North-West wind will cause South-East waves, therefore.

For moored ships, only the true wind speed and direction determine the longitudinal and lateral forces and the yaw moment on the ship, as given in Figure 2-2. Because of the absence of a steady velocity of the structure, the relative wind is similar to the true wind:

$$V_{rw} = V_{tw} \text{ and } \alpha_{rw} = \alpha_{tw} \tag{2.8}$$

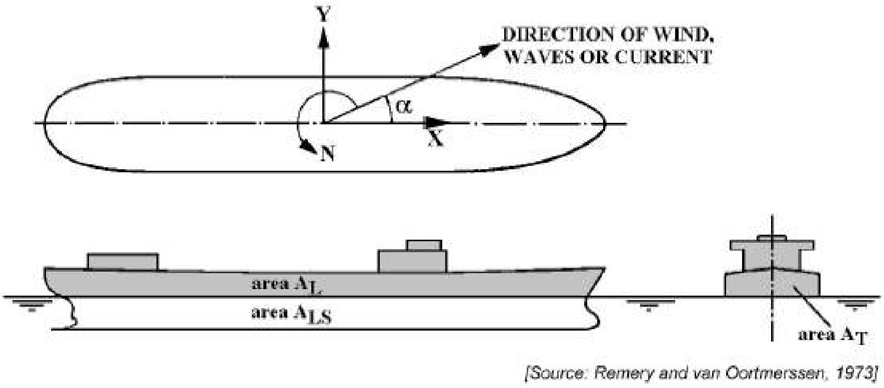

Figure 2-2 Definitions used for force and moments (Journee & Massie, 2001)

The total force and moment experienced by an object exposed to the wind is partly of viscous origin (pressure drag) and partly due to potential effects (lift force). For blunt bodies, the wind force is regarded as independent of the Reynolds number and proportional to the square of the wind velocity.

The gust wind-loading component is simulated by the wind gust spectrum. Several wind spectra exist. It should be emphasized that a wind spectrum is selected that best represents the actual geographical area the floater is located. Wind spectra are generally described with several parameters making it relatively easy to make input errors. Checking of wind spectrum energies and shapes is therefore considered essential. The most commonly used wind spectra are the API and NPD spectra. In this report, NPD spectrum used for dynamic wind load as per recommended by API RP 2SK.

Due to its importance, the wind load coefficients are usually determined based on wind tunnel tests. These tests are very often conducted early in the design process. In case of significant changes to the deck or topside structures during detail design, these wind tunnel tests may have to be repeated.

Remery and van Oortmerssen (1973) collected the wind data on 11 various tanker hulls. Their wind force and moment coefficients were expanded in Fourier series as a function of the angle of incidence. From the harmonic analysis, it was found that a fifth order representation of the wind data is sufficiently accurate, at least for preliminary design purposes:

$$C_{Xw} = a_0 + \sum_{n=1}^{5} a_n \sin(n.\alpha_{rw}) \tag{2.9}$$

$$C_{Yw} = \sum_{n=1}^{5} b_n \sin(n.\alpha_{rw}) \tag{2.10}$$

$$C_{Nw} = \sum_{n=1}^{5} c_n \sin(n.\alpha_{rw}) \tag{2.11}$$

with wind coefficients as listed below.

Table 2-1 Wind coefficients for various tanker hull (Journee & Massie, 2001)

Tanker No. Length L_{pp} Condition Bridge Location	1 loaded at $\frac{1}{2}L$	2 ballast at $\frac{1}{2}L$	3 loaded aft	4 ballast aft	5 225 m loaded at $\frac{1}{2}L$	6 225 m ballast at $\frac{1}{2}L$	7 225 m loaded aft	8 225 m ballast aft	9 172 m loaded aft	10 150 m loaded aft	11 150 m ballast aft
a_0	-0.131	-0.079	-0.028	0.014	-0.074	-0.055	-0.038	-0.039	-0.042	-0.075	-0.051
a_1	0.738	0.615	0.799	0.732	1.050	0.748	0.830	0.646	0.487	0.711	0.577
a_2	-0.058	-0.104	-0.077	-0.055	0.017	0.018	0.031	0.034	-0.072	-0.082	-0.058
a_3	0.059	0.085	-0.054	-0.017	-0.062	-0.012	0.012	0.024	0.109	0.043	0.051
a_4	0.108	0.076	0.018	-0.018	0.080	0.015	0.021	-0.031	0.075	0.064	0.062
a_5	-0.001	0.025	-0.018	-0.058	-0.110	-0.151	-0.072	-0.090	-0.047	-0.038	0.006
b_1	0.786	0.880	0.697	0.785	0.707	0.731	0.718	0.735	0.764	0.819	0.879
b_2	0.039	0.004	0.036	0.014	-0.013	-0.014	0.032	0.003	0.037	0.051	0.026
b_3	0.003	0.003	0.018	0.014	0.028	0.016	0.010	0.004	0.052	0.023	0.014
b_4	0.034	-0.004	0.028	0.015	0.007	0.001	-0.001	-0.005	0.016	0.032	0.031
b_5	-0.019	-0.003	-0.023	-0.020	-0.044	-0.025	-0.040	-0.017	-0.003	-0.032	-0.029
$10 \cdot c_1$	-0.451	-0.338	-0.765	-0.524	-0.216	-0.059	-0.526	-0.335	-1.025	-0.881	-0.644
$10 \cdot c_2$	-0.617	-0.800	-0.571	-0.738	-0.531	-0.730	-0.596	-0.722	-0.721	-0.681	-0.726
$10 \cdot c_3$	-0.110	-0.080	-0.166	-0.175	-0.063	-0.035	-0.111	-0.090	-0.345	-0.202	-0.244
$10 \cdot c_4$	-0.110	-0.096	-0.146	-0.089	-0.073	-0.017	-0.113	-0.047	-0.127	-0.145	-0.076
$10 \cdot c_5$	-0.010	-0.013	0.021	-0.021	0.024	-0.013	0.099	0.067	-0.022	0.039	0.024

Figure 2-3 shows, as an example, the measured wind forces and moment together with their Fourier approximation, for one of the tankers.

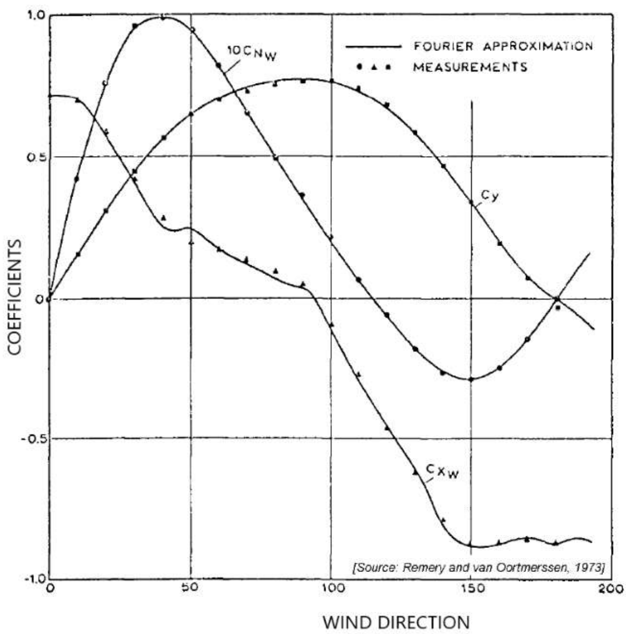

Figure 2-3 Example of wind load coefficients (Journee & Massie, 2001)

2.2.3 Current Loads

There are some independent phenomena that cause the occurrence of current, i.e.: the ocean circulation system resulting in a steady current, the cyclical change in lunar and solar gravity causing tidal currents, wind and differences in sea water density. The steady wind velocity at the water surface is about 3 percent of the wind velocity at 10meter height. Tidal currents are of primary importance in areas of restricted water depth and can attain values up to 10 knots. However, such extreme velocities are rare; a 2-3 knots tidal current speed is common in restricted seas. The prediction of tidal currents is left for the oceanographers.

Although surface currents will be the governing ones for floating structures; the current distribution as a function of depth below the surface may also be of importance. For the design of a mooring system of a floating structure, the designer is especially interested in the probability that a certain extreme current velocity will be exceeded during a certain period of time. Observations obtained from current speed measurements are indispensable for this purpose. It may be useful to split up the total measured current in two or more components, for instance in a tidal and a non-tidal component, since the direction of the various components will be different, in general. The variation in velocity and direction of the current is very slow, and current may therefore be considered as a steady phenomenon.

The forces and moment exerted by a current on a floating object is composed of the following parts (Journee & Massie, 2001):

a) A viscous part, due to friction between the structure and the fluid, and due to pressure drag. For blunt bodies the frictional force may be neglected, since it is small compared to the viscous pressure drag.
b) A potential part, with a component due to a circulation around the object, and one from the free water surface wave resistance. In most cases, the latter component is small in comparison with the first and will be ignored.

The forces and moments, as given in Figure 2-2, exerted by the current on a floating structure can be calculated from:

$$X_c = \frac{1}{2}\rho.V_c^2.C_{Xc}(\alpha_c).A_{TS} \quad (2.12)$$

$$Y_c = \frac{1}{2}\rho V_c^2.C_{Yc}(\alpha_c).A_{LS} \quad (2.13)$$

$$N_c = \frac{1}{2}\rho.V_c^2.C_{Nc}(\alpha_c).A_{LS}.L \quad (2.14)$$

in which:

X_c	=	steady longitudinal current force (N)
Yc	=	steady lateral current force (N)
Nc	=	steady horizontal current moment (Nm)
ρ	=	density of water (kg/m3)
Vc	=	relative current velocity (m/s)
αc	=	relative current direction (-), from astern is zero
$ATS \approx B.T$	=	transverse projected current area (m2)
$ALS \approx L.T$	=	lateral projected current area (m2)
L	=	length of the ship (m)
B	=	breadth of the ship (m)
T	=	draft of the ship (m)
C-C(αc)	=	αc - dependent current load coefficient (-)

Remery and van Oortmerssen (1973) published current loads on several tanker models of different sizes, tested at MARIN. The coefficients C_{XC}, C_{YC} and C_{NC} were calculated from these results. A tanker hull is a rather slender body for a flow in the longitudinal direction and consequently the longitudinal force is mainly frictional. The total longitudinal force was very small for relatively low current speeds and could not be measured accurately. Moreover, extrapolation to full scale dimensions is difficult, since the longitudinal force is affected by scale effects.

For mooring problems, the longitudinal force will hardly be of importance. An estimate of its magnitude can be made by calculating the flat plate frictional resistance, according to the ITTC skin friction line as given in equation:

$$ITTC - 1957: \; C_f = \frac{0.075}{(log_{10}(Rn) - 2)^2} \quad (2.15)$$

$$X_c = \frac{0.075}{(log_{10}(Rn)-2)^2} . \frac{1}{2} \rho V_c^2 . cos\alpha_c . |cos\alpha_c| . S \tag{2.16}$$

while:

$$Rn = \frac{Vc.|cos\alpha_c|.L}{v} \tag{2.17}$$

with:

$S \approx L.(B+2T)$	=	wetted surface of the ship (m^2)
L	=	length of the ship (m)
B	=	breadth of the ship (m)
T	=	draft of the ship (m)
Vc	=	current velocity (m/s)
αc	=	current direction (-), from astern is zero
ρ	=	density of water (ton/m^3)
Rn	=	Reynolds number (-)
v	=	kinematic viscosity of water (m^{2}s)

Extrapolation of the transverse force and yaw moment to prototype values is no problem. For flow in the transverse direction a tanker is a blunt body and, since the bilge radius is small, flow separation occurs in the model in the same way as in the prototype. Therefore, the transverse force coefficient and the yaw moment coefficient are independent of the Reynolds number.

The coefficients for the transverse force and the yaw moment were expanded by MARIN in a Fourier series, as was done for the wind load coefficients as described in a previous section:

$$C_{Yc} = \sum_{n=1}^{5} b_n \sin(n.\alpha_c) \tag{2.18}$$

$$C_{Nc} = \sum_{n=1}^{5} c_n sin(n.\alpha_c) \tag{2.19}$$

The average values of the coefficients b_n and c_n for the fifth order Fourier series, as published by Remery and van Oortmerssen (1973), are given in the table below.

Table 2-2 Coefficient b_n and c_n for current load coefficients (Journee & Massie, 2001)

n	b_n	$10 \cdot c_n$
1	0.908	-0.252
2	0.000	-0.904
3	-0.116	0.032
4	0.000	0.109
5	-0.033	0.011

These results are valid for deep water. For shallow water, the transverse current force and moment coefficients have to be multiplied by a coefficient, which is given in Figure 2-4. The influence of the free surface is included in the data given on the coefficients b_n and c_n in the previous table. This influence, however, depends on the water depth and on the Froude number, and consequently changes if the current velocity or the tanker dimensions' change. For the condition to which these data apply, deep water and a prototype current speed in the order of 3 knots, the effect of the free surface is very small. For the case of a small clearance under the keel and a current direction of 90 degrees, damming up of the water at the weather side and a lowering of the water at the lee side of the ship occurs.

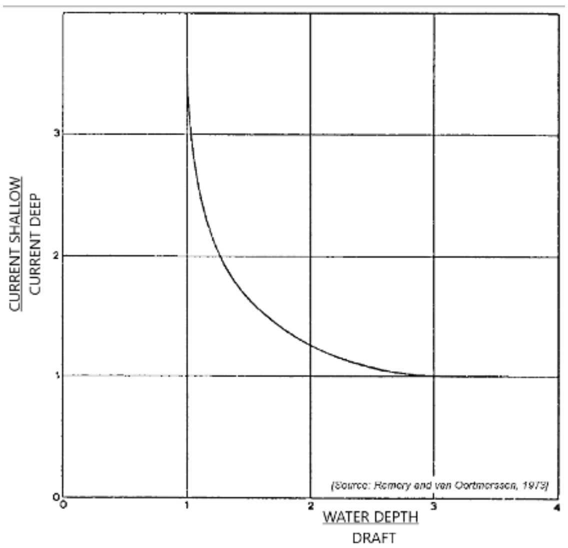

Figure 2-4 Influence of water depth on transverse current load on a tanker (Journee & Massie, 2001)

2.2.4 Wave Loads

Wave loads on floating structures as well as their responses to those loads can be split into several components. Firstly, there are wave loads which have the same frequencies as the waves and are linearly proportional in amplitude to the wave amplitudes. These are known as first order wave forces. Secondly, there are wave load components which have frequencies both higher and lower than the frequencies of the waves. These forces are proportional to the square of the wave amplitudes and known as second order wave forces.

Low frequency second order wave forces have frequencies which correspond to the frequencies of wave groups present in irregular waves. These forces, which, beside containing time-varying components, also contain a non-zero mean component, are known as wave drift forces. This name is a consequence of the fact that a vessel, floating freely in waves, will tend to drift in the direction of propagation of the waves under influence of the mean second order forces (Journee & Massie, 2001). High frequency second order forces contain frequencies corresponding to double the frequency of the waves (also known as sum frequencies). The horizontal motions response of moored structures to these forces is generally small.

As the floating structure are usually had a large volume, hence the inertia effect will be dominant. This implies that radiation/diffraction analyses need to be performed with a suitable analysis tool. A linear radiation/diffraction analysis will usually be sufficiently accurate. The term 'linear' means that the velocity potential is proportional to the wave amplitude, and that the average wetted area of the floater up to the mean water line is considered. The analysis gives first order excitation forces, hydrostatics, potential wave damping, added mass, first order motions in rigid body degrees of freedom and second order mean drift forces/moments. The mean wave drift forces only dependent on first order quantities, and can therefore be calculated in a linear analysis.

2.2.5 First Order Wave Loads

The most common practice used to analyze the linear steady state response of large-volume structures in regular waves are Panel methods. It is based on potential theory, assumed that the oscillation amplitudes of the fluid and the body are small relative to cross-sectional dimension of the body. The methods can only predict damping due to radiation of surface waves and added mass, yet they do not cover viscous effects. In linear analysis of response amplitude operator (RAO), forces and response are proportional to wave amplitude and response frequency are primarily at the wave frequency (WF).

The time-averaged value of this wave load and the resulting motion component are zero. Moored vessel exposed to large first order wave forces, which are the only contribution to the wave frequency motion for mooring analysis.

2.2.6 Second Order Wave Forces

Second order wave forces include steady force, a wide range of low frequency forces (which will excite surge, sway and yaw of a moored floating system) and high frequency forces (which will excite roll, pitch and heave springing of a TLP). The most common way to solve non-linear wave-structure problems is to use perturbation analysis with the wave amplitude as a small parameter. The non-linear problem is solved in second-order (Faltinsen, 1990).

The effects of second order wave forces are most apparent in the behavior of anchored or moored floating structures. Low frequency wave forces are normally an order of magnitude smaller than wave frequency forces, however their effect could be significant since the low frequencies are close to natural frequencies of the system. The vessel's natural frequencies in surge, sway and yaw are typically quite low and so the low frequency wave drift loads can generate large slow drift excursions in these directions.

2.2.6.1 Mean Wave Drift Forces

While the diffraction theory gives the first order force, inclusion of the second-order term from steeper waves may produce forces that are of the second order. The time independent portion of this force is called the steady wave drift force. Therefore, all quantities in the second order are included in the expression for the steady drift force. the magnitude of steady drift force is expected to be small. Its magnitude is generally of the order of 5% of the first-order force, which is often the order of uncertainty in the force computation. Then, why is it important in a design of an offshore structure? It is generally not that important for an offshore structure, unless a moored floating structure possesses a soft mooring stiffness in a certain degree of freedom. Examples of such systems are the surge and the heave of a catenary moored FPSO or semi, surge of a TLP, etc. Since the initial stiffness characteristics of such systems are quite low, even a small steady force induces a large displacement. Thus, under this steady load, the structure takes on a displaced position. This large displacement may affect its riser to have a large initial angle. which may be operationally limiting.

2.2.6.2 Slow-Drift Wave Forces

Mean and slowly varying wave drift forces in a random sea has been studied by Hsu and Blenkarn (1970) also Remery and Hermans (1971) using results of model tests with a rectangular barge with breadth B. It was moored in irregular head waves to a fixed point by means of a bow hawser. The wave amplitudes provide information about the slowly varying wave envelope of an irregular wave train. The wave envelope is an imaginary curve joining successive wave crests (or troughs), where the entire water surface motion takes place with the area enclosed by these two curves.

It seems logical in the light of the earlier results to expect that the square of the envelope amplitude will provide information about the drift forces in irregular waves. To do this, one would (in principle) make a spectral analysis of the square of this wave envelope. In other words, the spectral density of the square of the wave amplitude provides information about the mean period and the magnitude of the slowly varying wave drift force. In practice, it is very difficult to obtain an accurate wave envelope spectrum due to the long wave record required. Assuming about 200-250 oscillations are required for an accurate spectral analysis and that the mean period of the wave envelope record is about 100 seconds, the total time that the wave elevation has to be recorded can be up to 7 hours.

Another very simple method is based on individual waves in an irregular wave train. Assume that the irregular wave train is made up of a sequence of single waves of which the wave amplitude is characterized by the height of a wave crest or the depth of a wave trough, ζ_{ai}, while the period, T_i, is determined by the two adjacent zero crossings.

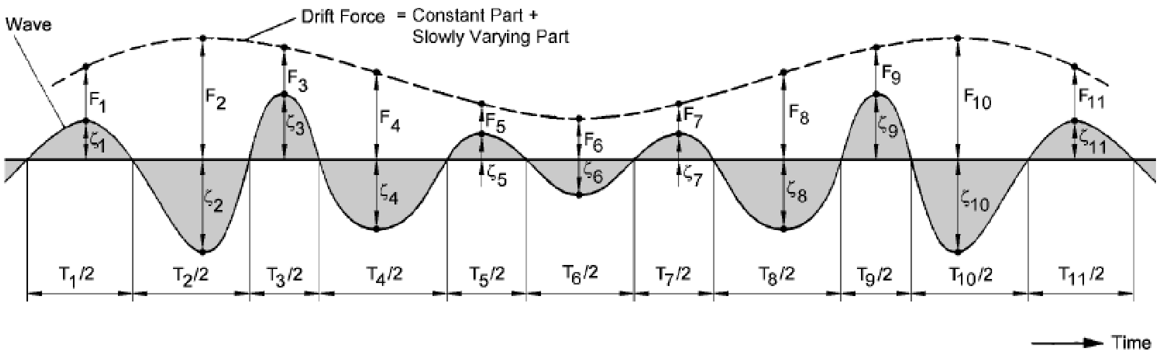

Figure 2-5 Wave drift force obtained from a wave record (Journee & Massie, 2001)

Each of the so obtained single waves (one for every crest or trough) is considered to be one out of a regular wave train, which exerts (in this case) a surge drift force on the barge:

$$F_i = \frac{1}{2}\rho g[R(\omega_i).\zeta_{ai}]^2.\mathrm{B} \tag{2.20}$$

$$\omega_i = \frac{2\pi}{T_i} \tag{2.21}$$

where:

$R(\omega_i)$ = reflection coefficient (=1.0)

When this is done for all wave crests and troughs in a wave train, points on a curve representing a slowly varying wave drift force, F(t), will be obtained. This drift force consists of a slowly varying force (the low-frequency wave drift force) around a mean value (the mean wave drift force).

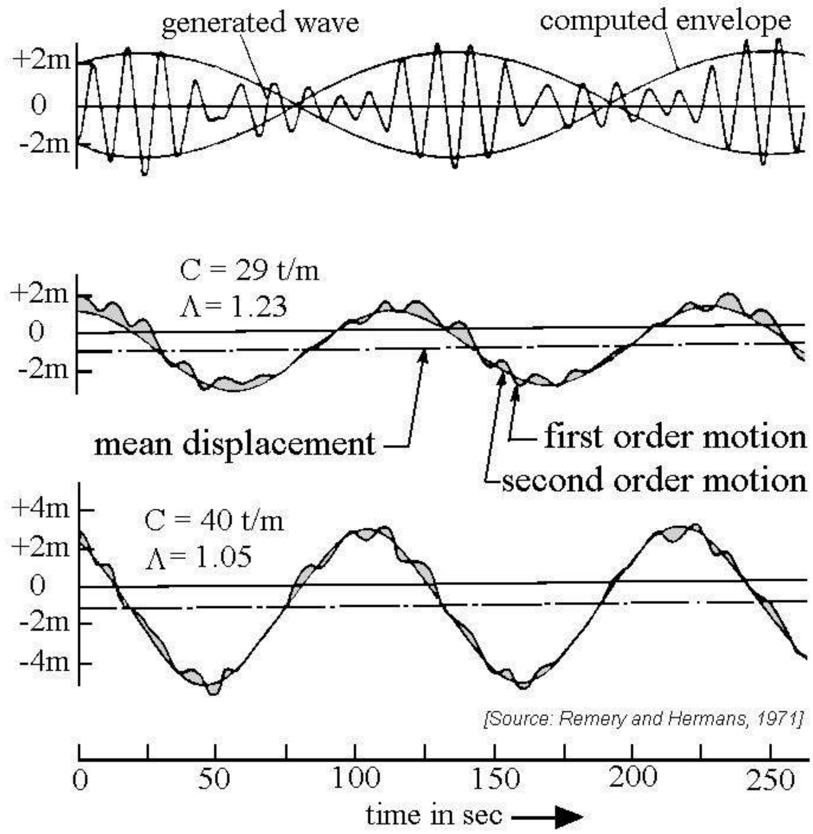

Figure 2-6 Low frequency surge motion of a barge (Journee & Massie, 2001)

2.2.7 Mooring System

Mooring systems are used for anchoring a floating structure to the sea floor with one of catenary, taut or semi-taut lines. The lines are attached to the floating structure at different points, where the lower ends of the lines anchored at the seabed. Mooring lines consist of either steel chain, rope or combination of both. The ropes itself are available in construction from steel, natural fibre and synthetic fibre. It is common that each line composed of two or more of different segment material, e.g. heavy chain at the bottom segment and wire rope at the mid/upper segment. This gives greater stiffness and lighter line weight compared to the use of chain or wire only (Faltinsen, 1990).

Mooring system is intended to keep the floating structure safely at a required position and to limit the horizontal offset of the floating structure to an acceptable limit so that:

- Maintain the integrity of risers and umbilicals
- Maintain the safe distance to other structures/facility
- Control the mean offset and low-frequency motions
- Absorb the wave-frequency motions

In a mobile mooring system, the floating structure anchored at a specific location for a period less than 5 years e.g. mooring of Mobile Drilling Units. For a permanent mooring system, the structure remains at the same location for more than 5 years e.g. mooring of FPSOs. Mobile Drilling Units (MODUs) have different anchor requirements than permanently moored systems. The permanent mooring is designed to meet the strength and fatigue requirements of a project and the anchors are usually not retrieved. Anchors and mooring lines for temporary moorings need to be more robust to withstand repetitious handling, installation and retrieval (Saidee, 2015).

Based on its configuration, mooring system can be divided into two categories known as single point mooring and spread mooring system. It is important to recognize that single point mooring and spread mooring have different performance characteristics, both in terms of vessel motion which can affect topside operations and offloading systems. One of single point mooring is turret mooring system which will be the object of this study.

Turret Mooring

Single point mooring is often used for ship-shaped floating structures such as floating production, storage and offloading structures (FPSOs) and allows the connected vessel to vary its heading (weathervane). One example is turret mooring system.

The turret can be mounted externally from the vessel bow or stern with appropriate reinforcements or internally within the vessel. The chain table can be above or below the waterline. The turret also could be integrated into a vertical riser system which is attached to the bow or stern of the vessel (or internally) through some kind of mechanism that allow articulation (Chakrabarti, 2005). Floating Production Unit with external turret mooring and internal turret mooring system are presented in Figure 2-7 and Figure 2-8 respectively.

Figure 2-7 FPSO with external turret mooring system (www.ptsc.com.vn)

Figure 2-8 FPSO with internal turret mooring system (www.2b1stconsulting.com)

2.2.8 Mooring Analysis

Floating structures and their mooring systems experience interaction under environmental forces. The dynamic mooring line tension is normally predicted based on the vessel motions which are first determined. Floating structures considered herein are ships, semi-submersibles, spars, etc., and they are usually modelled as rigid bodies in motion analysis.

Vessel motion response in a stationary and short-term sea state can be split into three components:

- Mean displacement due to mean environmental loads
- Low frequency (LF) motions with natural periods of the moored vessel in surge, sway and yaw directions due to LF wind loads and second order wave loads
- Motions at the frequency of incoming waves due to first order wave loads

Mean offset of the floating vessel is determined at an equilibrium position under the combined mean forces of waves (mean wave drift), wind and current by considering the nonlinear restoring forces of the mooring system. Dynamic motions are established at the equilibrium position of the vessel.

Mooring analysis includes both the vessel motion analysis and the analysis of mooring line tension. Vessel motion responses are caused by steady wave, wind and current forces, wave frequency (WF) and low frequency (LF) wave loads as well as LF wind forces. While the LF wave forces are relatively small compared with the WF forces, the effect on the vessel motions can be significant due to the resonance of the entire moored structure. Moreover, mooring line tension is mainly induced by the motions at the fairlead and the contribution of wave forces directly acting on the lines is relatively small. Thus, the tension response consists of the mean, WF and LF components similar to the motion response (Gao, 2008).

Coupled analysis where both the vessel motion and mooring line tension responses shall be performed by applying either a frequency domain or a time domain method. It shall be possible to document that the chosen calculation program is applicable for the particular anchoring system and on the particular location.

A picture of catenary line is shown in Figure 2-9. Horizontal seabed is assumed and the bending stiffness effect are neglected. The latter is generally suitable both for chains and wires with a large radius of curvature. Line dynamic effects also neglected at this stage.

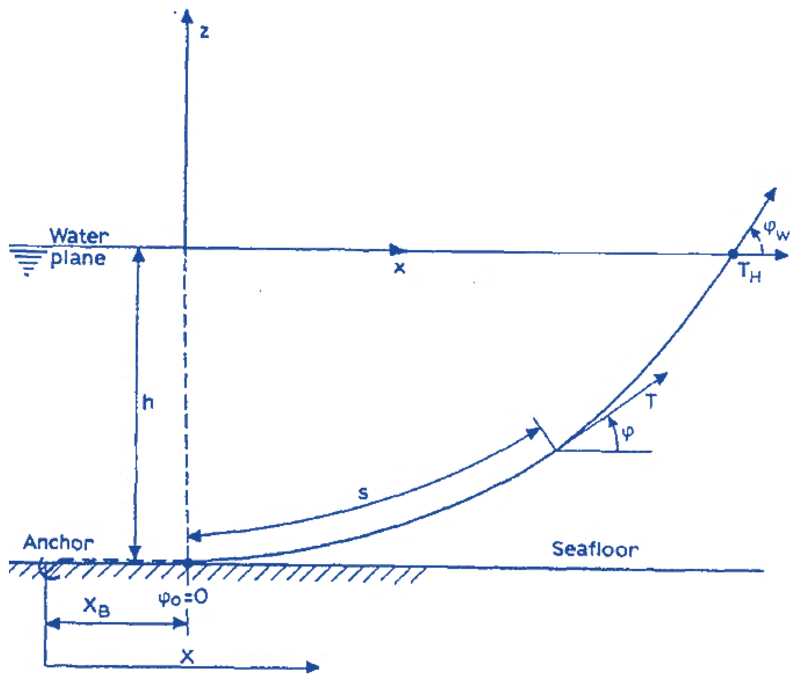

Figure 2-9 Catenary mooring line (Faltinsen, 1990)

An element of catenary line is shown in. The term *w* is the weight per unit length of the line in water, *A* is the cross-sectional area of the mooring line, *E* is the elastic modulus and *T* is the line tension. Forces *D* and *F* acting on the element are the mean hydrodynamic forces per unit length in the normal and tangential direction respectively (Chakrabarti, 2005).

From Figure 2-10, considering in-line and transverse forcing gives:

$$dT - \rho gAdz = \left[wsin\emptyset - F\left(\frac{T}{EA}\right)\right] ds \quad (2.22)$$

$$Td\emptyset - \rho gAzd\emptyset = \left[wcos\emptyset + D(1 + \frac{T}{EA})\right] ds \quad (2.23)$$

Ignoring forces *F* and *D* together with elasticity allows simplification of the equations, though it is noted that elastic stretch can be very important and needs to be considered when lines become tight or for a large suspended line weight (large 10 or deep waters).

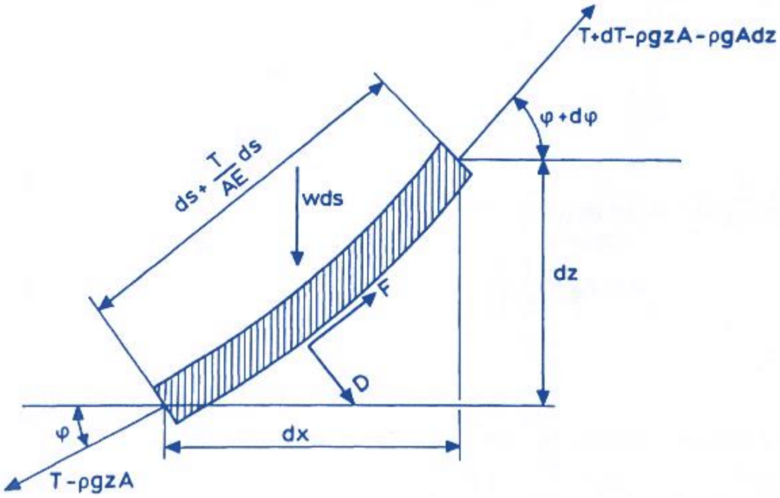

Figure 2-10 Forces on an element of mooring line (Faltinsen, 1990)

With the above assumptions, we can obtain the suspended line length s and vertical dimension h as:

$$s = \left(\frac{T_H}{w}\right) sinh\left(\frac{wx}{T_H}\right). \tag{2.24}$$

$$h = \left(\frac{T_H}{w}\right)\left[cosh\left(\frac{wx}{T_H}\right) - 1\right] \tag{2.25}$$

giving the tension in the line at the top, written in terms of the catenary length s and depth d as:

$$T = \frac{w(s^2+d^2)}{2d} \tag{2.26}$$

The vertical component of line tension at the top end becomes:

$$T_z = ws \tag{2.27}$$

while the horizontal component of tension is constant along the line and is given by:

$$T_H = Tcos\emptyset_w \tag{2.28}$$

above analysis assumes that the line is horizontal at the lower end replicating the case where a gravity anchor with no uplift is used.

Typical mooring analysis requires summation of the effects of up to 16 or more lines with the surface vessel position co-ordinates near the water plane introducing three further variables. The complexity of this calculation makes it suitable for implementing within computer software.

For mooring lines laying partially on the seabed, the analysis is modified using an iteration procedure, so that additional increments of line are progressively laid on the seabed until the suspended line is in equilibrium. Furthermore, in many situations, multi-element lines made up of varying lengths and physical properties are used to increase the line restoring force. Such lines may be analyzed in a similar manner, where the analysis is performed on each line element, and the imbalance in force at the connection points between elements is used to establish displacements through which these points must be moved to obtain equilibrium (Chakrabarti, 2005).

2.2.9 Fatigue Damage Assessment

As described previously, fatigue is cumulative damage on structure caused by cyclic loading. The content in this section are mostly taken from API RP 2SK. Generally, the load amplitude of each cycle is not large enough to cause the structural failure by itself. However, failure could occur when the accumulated damage experienced by the structure reaches a critical level. In high cycle fatigue problem of offshore structures, one often employs S-N curve and linear Palmgren-Miner law for the fatigue life prediction. The S-N curves are obtained through multiple fatigue tests executed at different stress levels, where considerable statistical scatter in the fatigue life will be observed. The deviation of fatigue life despite similarity in test specimen and loading conditions is due to sample-to-sample material differences, microscopic defects, surface roughness as well as human errors such as specimen alignment.

Fatigue life estimates are made by comparing the long-term cyclic loading in a mooring line component with the resistance of that component to fatigue damage. For mooring systems, a T-N approach is normally used. This approach uses a T-N curve, which gives the number of cycles to failure for a specific mooring component as a function of constant normalized tension range.

T-N curve proposed by API RP 2SK is used for calculating nominal tension fatigue life of mooring components.

$$NR^M = K \tag{2.29}$$

where:

N = number of cycles

R = ratio of tension range (double amplitude) to reference breaking strength (RBS)

L_m = ratio of mean load to reference breaking strength (RBS) for wire rope

For chain, RBS is taken as MBS (minimum breaking strength) of ORQ common chain link of the same size for ORQ, R3, R4, and R4S common or connecting links. For wire rope, RBS is the same as MBS. The values of M and K are provided in Table 2-3. Mooring component fatigue design curves are presented in Figure 2-11. These design curves indicate that studless chain has lower fatigue life than studlink chain. The above T-N curves should be used in conjunction with a factor of safety 3 as specified in API RP 2SK. The T-N curves for wire rope are only good for wire ropes protected from corrosion. Elements for corrosion protection include galvanizing, jacketing, blocking compound, and zinc filler wires. It should be noted that wire rope curves are mean load dependent, and a mean load of 30% MBL is assumed in the plot.

Table 2-3 *M* and *K* values (API, 2008)

Components	***M***	***K***
Common studlink	3.0	1000
Common studless link	3.0	316
Six/multi strand rope	4.09	$10^{(3.20-2.79Lm)}$
Spiral strand rope	5.05	$10^{(3.25-3.43Lm)}$

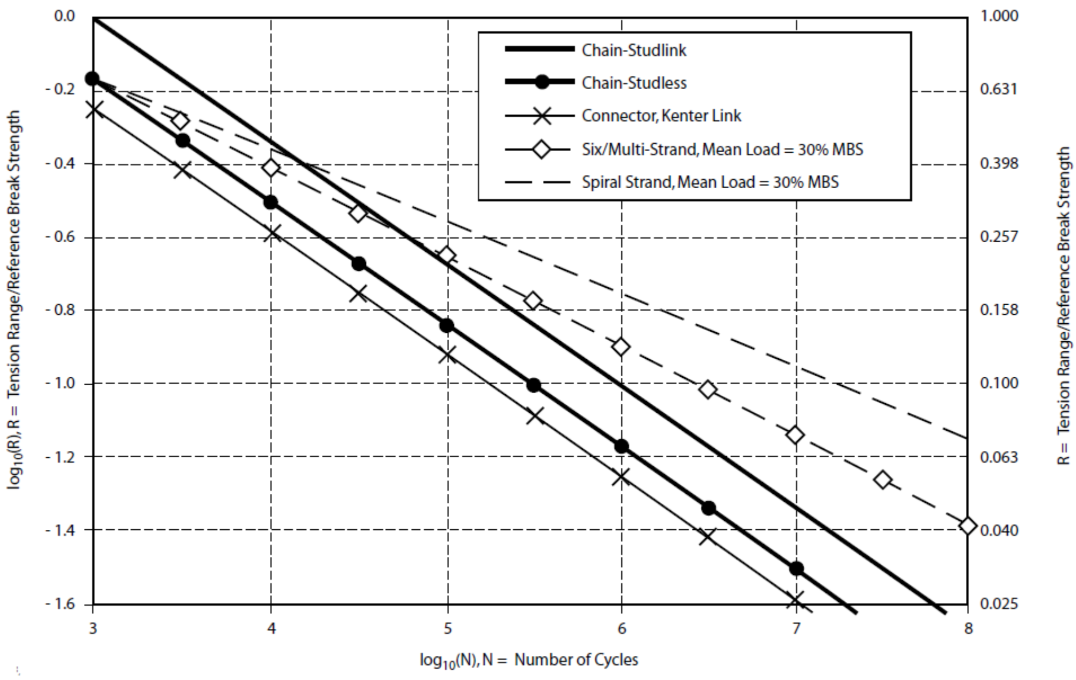

Figure 2-11 Mooring fatigue design curves (API, 2008)

In practical matters, cyclic loading of mechanical components is normally highly irregular, i.e. variable amplitude load conditions. To estimate the fatigue life of components undergoing such load histories the vastly used Palmgren–Miner rule is introduced here. The miner's rule is used to calculate the annual cumulative fatigue damage ratio *D*. The annual fatigue damage, accumulated in a mooring line component as a result of cyclic loading, is summed up from the fatigue damage arising in a set of environmental states chosen to discretize the long-term environment that the mooring system is subjected to:

$$D = \sum_{i=1}^{i=n} D_i \tag{2.30}$$

where:

D_i = annual fatigue damage to the component due to environmental state *i*

The discretization into $i = 1,\ldots,n$ environmental states should be sufficiently detailed to avoid any significant error in the total. Each environmental state is defined in terms of the wind, wave, and current parameters and directions required to compute mooring system responses. The probability of occurrence, *Pi*, is required for each environmental state. Then, the calculated fatigue life of the mooring system is:

$$L = \frac{1}{D}\ (years) \qquad (2.31)$$

The annual fatigue damage accumulated in an individual state may be computed as:

$$D_i = \frac{n_i}{K} E[R_i^M] \qquad (2.32)$$

where:

M and *K* are defined in Table 2-3.

n_i = the number of tension cycles encountered in state *i* per year.

$E[R_i^M]$ = the expected value of the normalized tension range Ri raised to the power *M*, in state i

In principle, fatigue failure occurs when the total damage *D* is larger or equals to 1, this means that 100% of the life is exhausted.

2.2.10 Rainflow counting

Fatigue life of a component can be obtained by using the adjusted stress amplitude of the component in respect to stress concentration factors of a notched member from an S-N curve of the selected material. Usually, the extraction of data points used in regression analysis of forming an S-N curve involves a scheme named constant amplitude stressing. In constant amplitude testing, the specimen goes through cycling between constant maximum and minimum stress levels. The difference of maximum and minimum stresses is the stress range and half this magnitude is called stress amplitude. The random stress variations of real world practices are recorded and presented in the same manner. To utilize the available S-N curves one should be able to identify the stress range and mean of individual cycles. This can be managed by rainflow counting methods. When facing highly irregular load histories with time the order in which how individual events should be considered as a cycle or otherwise is not clear so that the Palmgren-Miner rule can be employed (Yarveisy, 2015).

The stress cycles are counted from the local maxima (peaks) and minima (troughs) of the stress history by some cycle counting method. The simplest counting method is the so-called min-Max (Max-min) counting method, where the local maximum is paired with the preceding local minimum. The stress cycles in this method only consider the effect of local stresses, but ignore the global effect including large cycles. Therefore, this method is not capable of estimating the risk of fatigue failure, since it gives non-conservative (too small) fatigue damages.

The most frequently used rainflow counting method is developed on the hysteretic properties of material, where the cyclic stress-strain curves form hysteretic loops. The local maxima are represented by tops of the loops, while local minima by bottoms of the loops. The rainflow method is to identify the local minimum which should be paired with a local maximum to form a hysteretic loop. It is considered to give the most accurate fatigue life predictions.

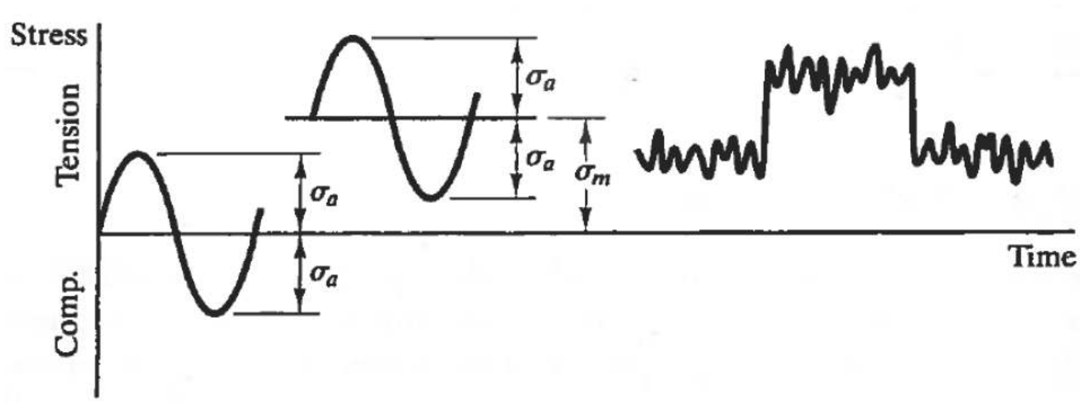

Figure 2-12 Stress time history. Left: Constant amplitude stressing. Right: Random stress time history (Yarveisy, 2015)

Rainflow cycle counting method was first proposed by Matsuishi and Endo (1968). Rainflow counting method is described in the following text. The rainflow counting method, is visualized by flow of falling rain on pagoda roofs. To implement this method let's assume that a stress time history is rotated so that the earliest time is on top. Such stress time history is shown in Figure 2-13. If rain drops on a pagoda roof it will flow downwards, following the rules mentioned below (Gao, 2008):

- Each rainflow begins at the beginning of the time series and successively at the inside of every peak and valley.
- Rainflow initiating at a peak (or a valley) drops down until it reaches opposite a peak more positive (or a valley more negative) than the peak (or the valley) it started from.
- Rainflow also stops when it meets the rainflow from a roof above.
- Rainflow must terminate at the end of the time series.
- The horizontal length of each rainflow is counted as a half cycle with that stress range.

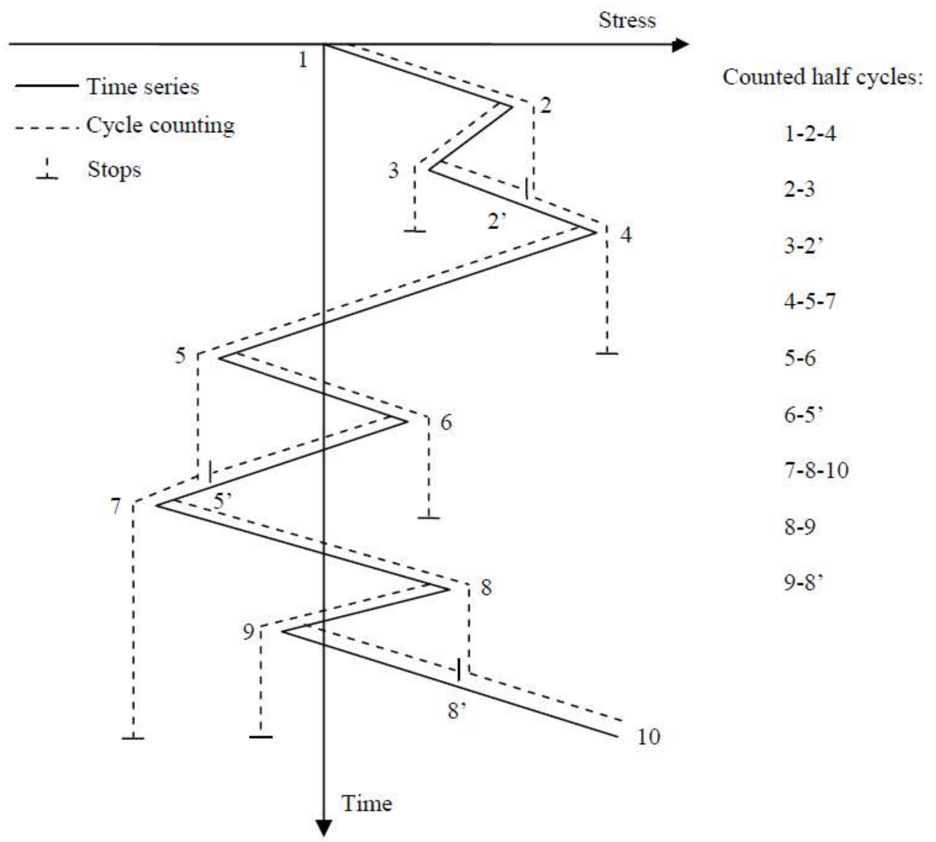

Figure 2-13 Rainflow cycle counting scheme (Gao, 2008)

The implementation methodology mentioned in rainflow counting algorithm of stress cycles is presented in Figure 2-13, where the flow starts at every peak and trough. As can be seen on Figure 2-13, the first rainflow starts from the beginning at 1 as a valley, the second one from the peak 2, the third one from the valley 3, and so on. The end at 10 is considered as a peak herein. There are totally 9 half cycles can be extracted from this time series.

The rainflow initiating at the valley 1 drops down at 2 and ends at 4 because the following valley 5 has smaller value than the initial point 1. Therefore, a half cycle of 1-2-4 has been identified. The same rule can be applied to determine the half cycle of 5-6. The second rainflow starts from 2 and stops at 3, which leads to a half cycle of 2-3, because the following peak 4 has larger value than 2. Similarly, the half cycles of 4-5-7 and 8-9 can be extracted based on the same rule due to the largest peak at 10.

The half cycles of 3-2', 6-5' and 9-8' are determined because the rainflows started at 3, 6 and 9, respectively, meet the rainflows from roofs above. The half cycle of 7-8-10 is formed because the time series ends at 10. When all of the 9 half cycles have been identified, the horizontal length of each cycle is used as an effective stress range to calculate the fatigue damage based on e.g. the linear damage accumulation law.

Various formats of the rainflow counting method are standardized and published in ASTM (2005). The rainflow counting method used in this thesis is a mathematical definition of rainflow counting. This more suitable approach to statistical analysis of rainflow ranges is introduced by Rychlik (1987).

3. METHODOLOGY

3.1 Research Method

Methodology applied for this research is shown in the following flowchart.

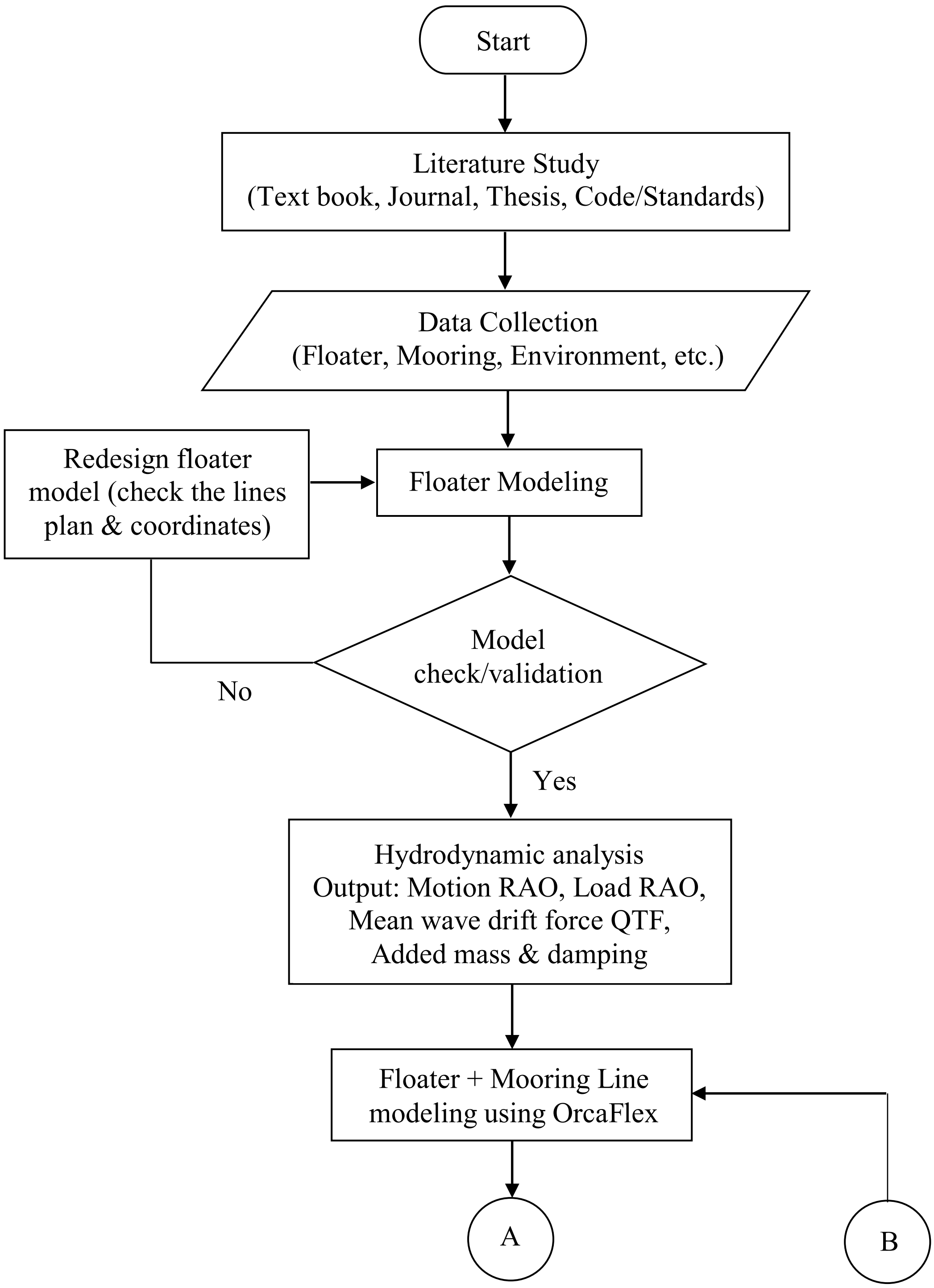

Figure 3-1 Analysis Methodology

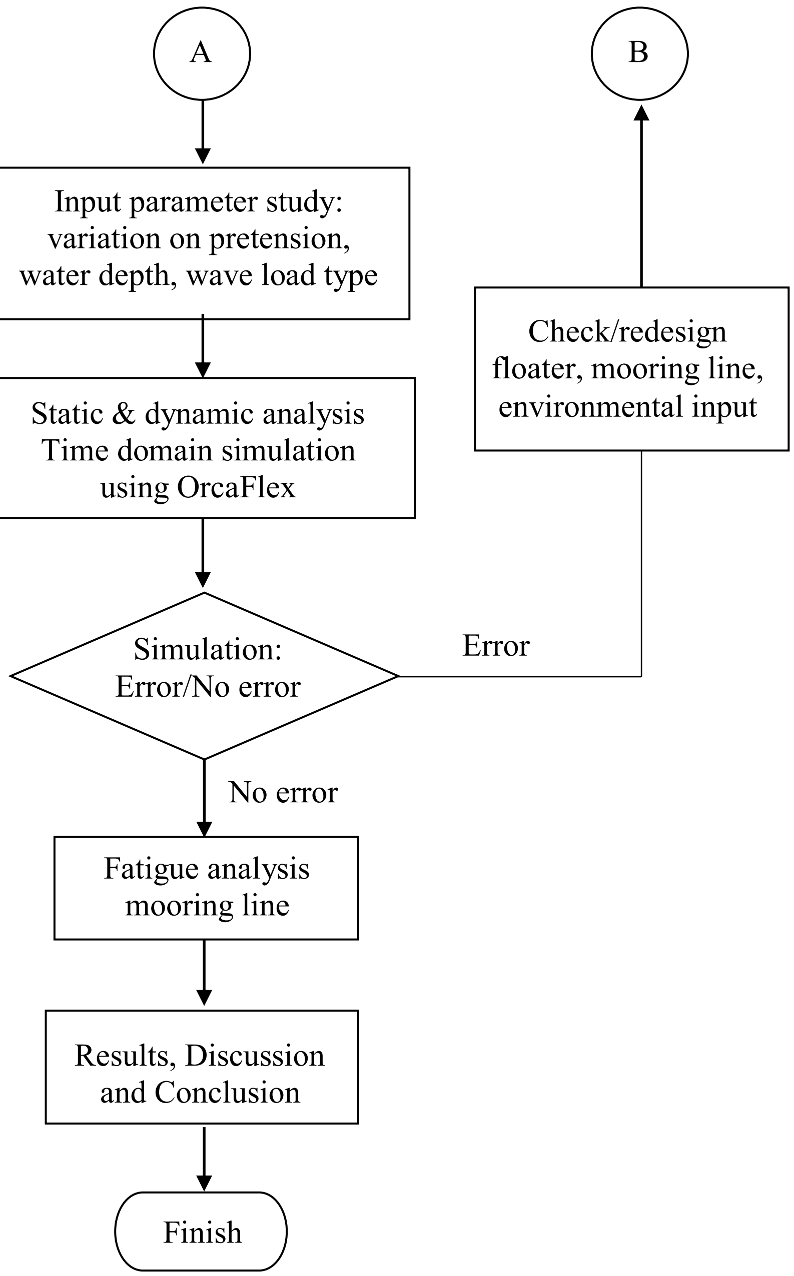

Figure 3-1 Analysis Methodology (Continued)

The details from above diagram explained in the following step:

a) Literature Study and Collecting Data

Study literature intended to obtain any information based on previous research, project, text books, etc. Information related to the effect of several parameters on mooring tension and fatigue damage of mooring lines are collected as references on this thesis. Collecting data covers floating structure data (e.g. dimension, hydrostatic, etc.), mooring lines data (e.g. mooring configuration, mooring components), environment data (e.g. wave, wind, current, scatter data).

b) Floating Structure Modelling

Numerical model of floating structure generated as markers (x, y and z-coordinate) to obtain surface/hull model using MOSES software. Only floater (FLNG) will be modelled here, mooring system will be modelled on the later step.

c) Model Check (Validation)

Once the floater model has been generated, it's shall be validated with existing/actual data, to ensure whether the model could be used for further analysis. Components of the model that will be checked against existing data are:

- Displacement
- Longitudinal Centre of Buoyancy (LCB)
- Vertical Centre of Buoyancy (VCB)
- Longitudinal Centre of Floatation (LCF)
- Keel to Metacentre Transversal (KMt)
- Keel to Metacentre Longitudinal (KMl)

d) Hydrodynamic analysis

Once the model satisfies the validation, a hydrodynamic analysis performed using frequency domain approach for all degree of freedom (6 DOF). This analysis intended to obtain hydrodynamic components such as: Motion Response Amplitude Operator (RAO), load RAO, added mass, damping, and wave drift force.

e) Floater and Mooring System Design

The next step is modelling floater and mooring systems in OrcaFlex software. Hydrodynamic characteristics resulted from frequency domain analysis were used as an input in OrcaFlex, including:

- Structure geometry

- Displacement structure
- Displacement RAO
- 1st order wave load (panel wave frequency load)
- Added mass and damping matrix
- Non-dimensional Quadratic Transfer Function as a transfer function of 2nd order wave load.
- Current forces
- Wind forces

Then, turret mooring system configuration and lines components were defined as per existing data. Mooring system configuration attached at the external turret are shown in Figure 3-2.

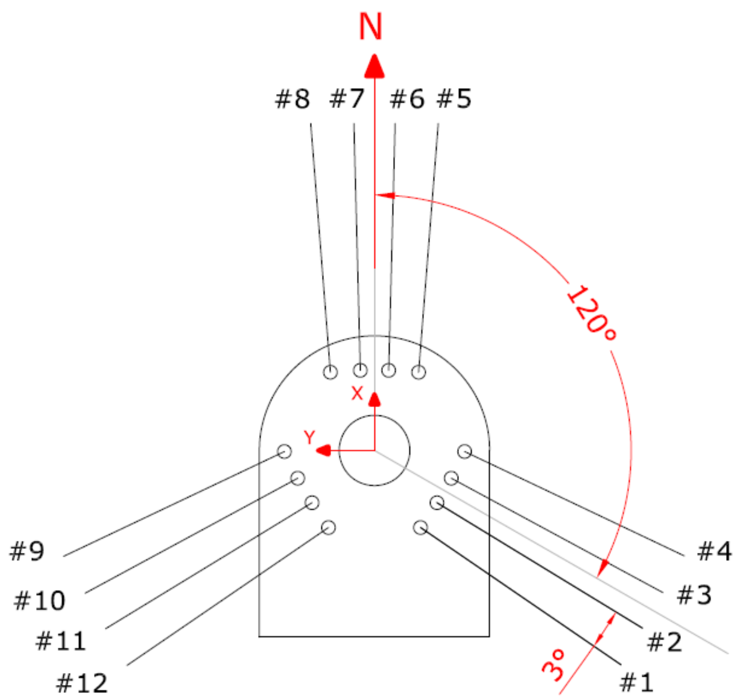

Figure 3-2 Mooring system configuration

f) Parameter Study

Several parameter studies that will be investigated are the influence of pretension, water depth and wave load type to fatigue life of mooring lines.

- Mooring pretension: mooring line pretension will be set to 14% MBL and 22% MBL, then will be compared to 18% MBL (Base case).

- Water depth: different value of water depth will be analyzed to investigate its effect. Water depth of 301m (50%WD) and 903m (150%WD) will be compared with actual water depth 602m (Base case).
- Wave Load type: To find out the effect of wave load, three cases were studied. Firstly is 1st order wave load only, secondly is 2nd order wave only, and combination of both, 1st order + 2nd order (Base case).

The mooring system configuration for various case studies are summarized in Table 3-1. There are total seven case studies in this research.

Table 3-1 Mooring system configuration for various case study

Description	**Case study**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Notes	Base case	Pretension 14%MBL	Pretension 22%MBL	50% water depth	150% water depth	1st order wave load	2nd order wave load
Pretension	18% MBL 3385 kN	2600 kN	4040 kN	3385 kN	3385 kN	3385 kN	3385 kN
Water depth	602 m	602 m	602 m	301 m	903 m	602 m	602 m
Wave load type	1st & 2nd order	1st & 2nd order	1st &2nd order	1st & 2nd order	1st & 2nd order	1st order load	2nd order load
Top chain	100.0 m	123.8 m	86.6 m	50.0 m	150.0 m	100.0 m	100.0 m
Wire rope	725.0 m	725.0 m	725.0 m	362.5 m	1087.5 m	725.0 m	725.0 m
Bottom chain	458.0 m	458.0 m	458.0 m	229.0 m	687.0 m	458.0 m	458.0 m

g) Static and Dynamic Analysis

Static analysis was performed to compute equilibrium position of moored structure. Then, dynamic analysis using time domain coupled approach was performed. This analysis intended to obtain moored structure offset and mooring lines forces. Dynamic coupled analysis performed for each parameter study. Each parameter study consists of several dynamic simulations (load case) depends on environmental scatter data.

h) Fatigue Analysis

Tension lines results from dynamic analysis will be proceed to obtain fatigue damage on the mooring lines. Fatigue damage calculated using Rainflow method. It uses a cycle counting technique to break down each random wave case into a series of half-cycles, and then sums the damage from each half-cycle according to Palmgren-Miner rule. This gives damage value for that load case. Total load case damage values are then summed for each load case to give the overall total damage. The T-N curve will also require to define *m* and *K* parameter as per API-RP-2SK.

3.2 Research Data

3.2.1 Vessel Data

Barge shaped FLNG, permanently moored with an external turret system was selected for this study. Main particular of the vessel are provided in Table 3-2.

Table 3-2 Vessel Particular

Vessel particular	Unit	Value
Loa	m	430
Lpp	m	381.4
Breadth	m	64
Depth	m	38
Displacement	ton	371020
Draft (even keel) - operating	m	15.5
VCG	m	24.36
VCB	m	7.91
LCB	m	191.4
LCF	m	191.581
KMt	m	30.7
KMl	m	814.7
Kxx	m	25.27
Kyy	m	105.86
Kzz	m	105.58

Vessel general arrangement presenting starboard side elevation view and deck plan view are provided in Figure 3-3. More detail picture is attached in Appendix F.

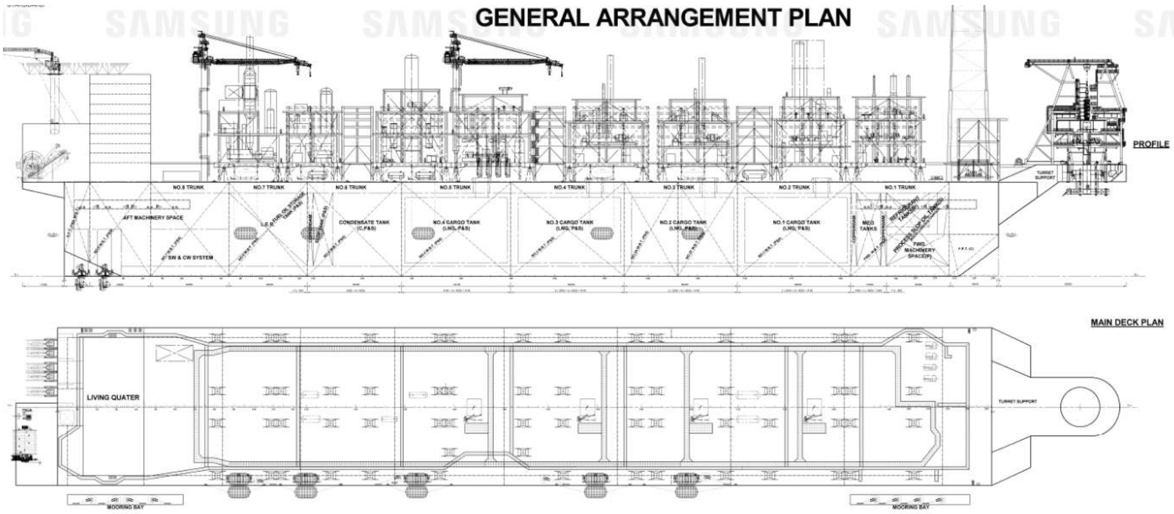

Figure 3-3 FLNG General Arrangement

3.2.2 Environmental Data

Fatigue wave scatter data were adopted from Bangka field located in offshore East Kalimantan, Indonesia. Wave occurrence on the scatter data identified by four variables, i.e. significant wave height (Hs), peak period (Tp), wind speed and wave direction. Wave and swell scatter data are presented in Table 3-3.

Table 3-3 Field Scatter Data

All year		Wind (m/s)	Sea wave direction								All Sea
Hs (m)	Tp (s)		N	NE	E	SE	S	SW	W	NW	
0.15	3.05	4.29	0.19	0.60	0.41	0.34	0.33	0.38	0.22	0.07	2.54
0.15-0.30	3.35	6.06	1.55	5.27	3.83	3.47	4.61	5.60	2.02	0.9	27.25
0.30-0.45	3.73	7.42	2.04	5.19	2.72	1.68	3.21	4.38	0.97	0.57	20.76
0.45-0.60	3.93	8.57	2.23	4.28	1.96	0.70	1.68	2.44	0.40	0.35	14.04
0.60-0.75	4.24	9.58	2.36	4.17	1.69	0.29	0.53	0.79	0.18	0.14	10.15
0.75-0.90	4.58	10.50	2.15	3.47	1.35	0.11	0.13	0.19	0.08	0.06	7.54

Table 3-3 Field Scatter Data (Continued)

All year		Wind	Sea wave direction								All
Hs (m)	Tp (s)	(m/s)	N	NE	E	SE	S	SW	W	NW	Sea
0.90-1.05	4.77	11.34	1.96	2.90	1.19	0.05	0.02	0.02	0.03	0.02	6.19
1.05-1.20	4.90	12.12	0.98	1.39	0.59	0.01	0.00	0.00	0.01	0.00	2.98
1.20-1.35	5.38	12.86	0.62	0.84	0.38	0.01	0.00	0.00	0.00	0.00	1.85
1.35-1.50	5.56	13.55	0.13	0.18	0.08	0.00	0.00	0.00	0.00	0.00	0.39
1.50-1.65	6.05	14.22	0.05	0.06	0.03	0.01	0.01	0.01	0.00	0.00	0.17
1.65-1.80	6.35	14.85	0.02	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.07
1.80-1.95			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.95			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotal			14.28	28.39	14.24	6.67	10.52	13.81	3.91	2.11	93.93
All year		Wind	Sea wave direction								All
Hs (m)	Tp (s)	(m/s)	N	NE	E	SE	S	SW	W	NW	Sea
0.15	9.67	0.00	0.00	1.70	0.00	0.00	0.00	0.00	0.00	0.00	1.70
0.15-0.30	9.74	0.00	0.00	2.17	0.00	0.00	0.00	0.00	0.00	0.00	2.17
0.30-0.45	9.50	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.05
0.15	11.64	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.15
0.15-0.30	12.02	0.00	0.00	1.76	0.00	0.00	0.00	0.00	0.00	0.00	1.76
0.30-0.45	12.22	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.25
Total											100.00

As can be seen on Table 3-3, each Hs, Tp and wave direction will represent one load case. The probability of occurrence of these conditions also be specified. Based on wave and swell scatter data above, the total number of load cases for fatigue analysis is 83 cases. In general, 8 to 12 reference directions provide a good representation of the directional distribution of a long-term environment. The required number of reference sea states should be in the range of 10 to 50 (DNVGL-OS-E301, 2015). Hence, the scatter data above has complied with DNVGL standard for mooring fatigue damage prediction.

Current data presented in Table 3-4 showing current speed at different depth. Current speed is measured at sea surface and modelled as Power Law method current profiles and assumed same in magnitude for all direction.

Table 3-4 Current speed

Depth (m)	Current speed (m/s)
0	0.680
50	0.672
300	0.616
602	0.006

3.2.3 Mooring Line Data

The external turret mooring system is used for station-keeping of the vessel. The mooring system which consist of 12 mooring lines in 3 groups of 4 lines is located in front of FP. The angle between the groups is 120deg, while the angle between mooring lines in each group is 3deg. Mooring leg general arrangement and chain table arrangement are presented in Figure 3-4 and Figure 3-5 respectively.

The mooring line are made of chain-wire-chain configuration. The top chain and bottom chain are made of 157mm grade R4 studless and 170mm grade R3 studless chain respectively. The steel wire rope is made of 131mm (steel section) spiral strand sheathed wire. The sheathing adds protection to the outer layer strands.

Table 3-5 Mooring line properties

	Top Chain	Steel Wire	Bottom chain
Type	Studless R4	Spiral strand – sheathed	Studless R3
Diameter (mm)	157	131	170
MBL (kN)	21234	18300	19692
Axial Stiffness-EA (kN)	1419594	1552000	1487895
Weight (ton/m)	0.487	0.0708	0.495

Table 3-6 Mooring line length

Mooring Group	Mooring Line	Top chain (m)	Steel Wire (m)	Bottom chain (m)	Anchor radius (m)
G1	1	100.0	725.0	458.0	1057.2
	2	100.0	725.0	458.0	1057.2
	3	100.0	725.0	458.0	1057.2
	4	100.0	725.0	458.0	1057.2
G2	5	100.0	725.0	458.0	1057.2
	6	100.0	725.0	458.0	1057.2
	7	100.0	725.0	458.0	1057.2
	8	100.0	725.0	458.0	1057.2
G3	9	100.0	725.0	458.0	1057.2
	10	100.0	725.0	458.0	1057.2
	11	100.0	725.0	458.0	1057.2
	12	100.0	725.0	458.0	1057.2

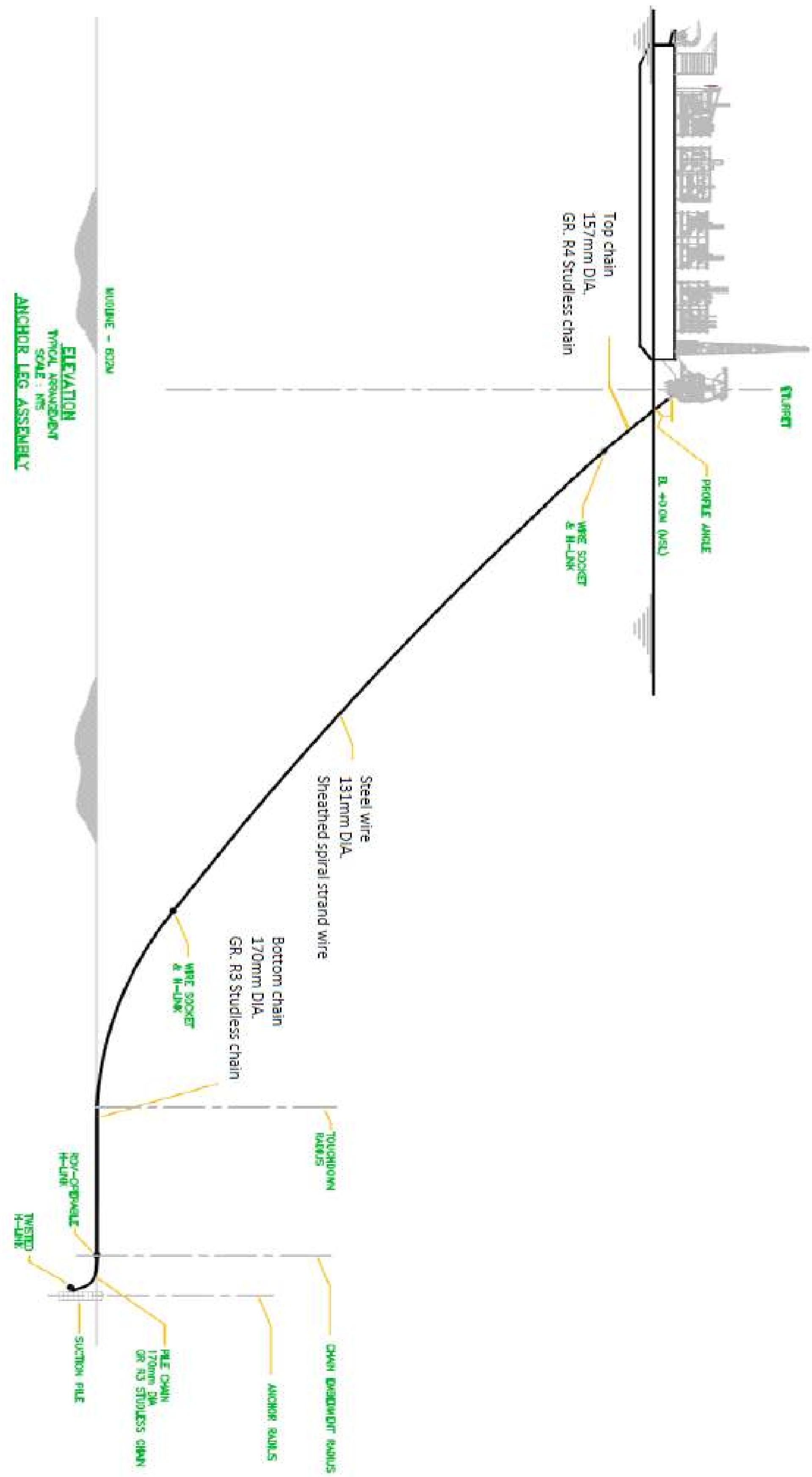

Figure 3-4 Mooring legs general arrangement (JTM, 2014)

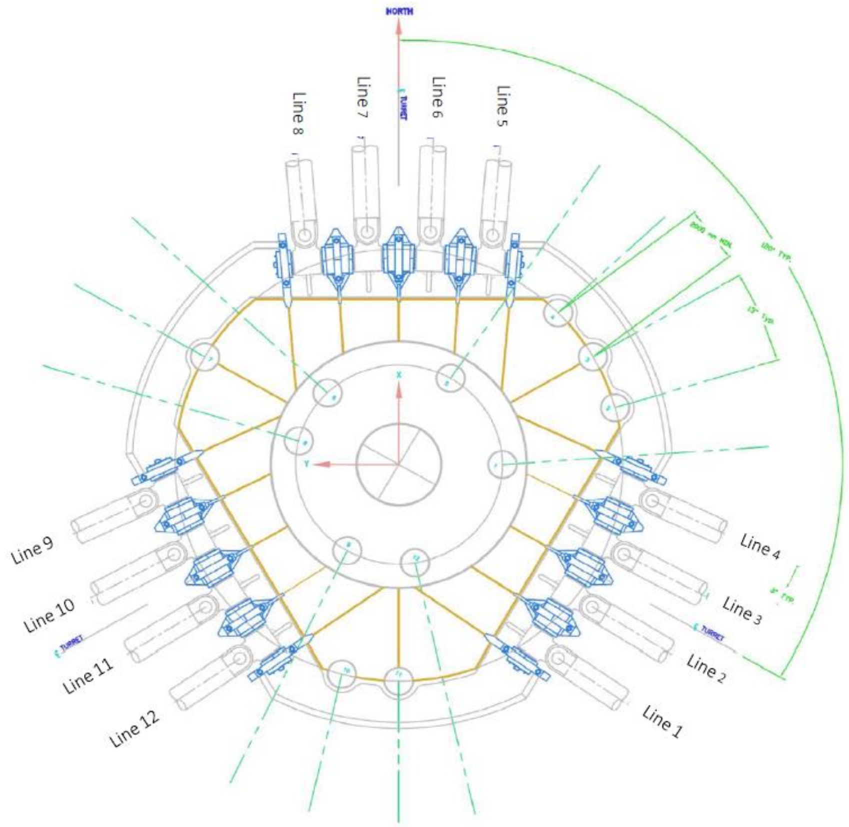

Figure 3-5 Chain table plan view (JTM, 2014)

3.2.4 Corrosion Allowance

Floating unit equipped with mooring lines which are positioned at the same location for 5 years or more required to carry out fatigue damage calculation. Corrosion allowance for chain, including wear and tear of chain need to be included in the calculation. A strength reduction equal to 0.4mm/year corrosion and wear over 30 years is considered in design of chain sections. It is assumed that no corrosion allowance applied for steel wire section due to the corrosion protection (sheathed). It shall be noted that in fatigue analysis, 50% of the chain's corrosion allowance shall be taken into account (DNVGL-OS-E301, 2015).

Table 3-7 presents corrosion allowance referred to mooring line diameter considering 30 years of service life.

Table 3-7 Corrosion allowance

Line Segment	$\emptyset_{initial}$ (mm)	MBL (kN)	Corrosion Allowance per year (mm)	$\emptyset_{corroded}$ (mm)	$MBL_{corroded}$ (kN)
Top chain	157	21234	0.4	151	18496
Steel wire	131	18300	-	131	18300
Bottom chain	170	19592	0.4	164	17317

3.3 Numerical Model

3.3.1 Vessel Model

Numerical model of floating unit completed in two different software. Firstly, a 3-D diffraction software MOSES is used to generate panel model of the vessel. Hydrostatic and hydrodynamic properties of the vessel also computed in this frequency domain based software. Secondly, floating unit and its mooring system modelled using software OrcaFlex, which will be discussed in later section. Results of vessel panel model from MOSES presented in Figure 3-6 to Figure 3-8.

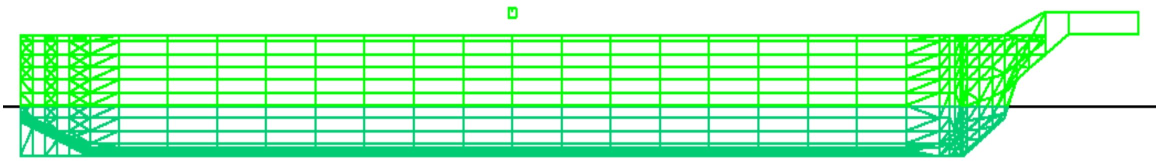

Figure 3-6 Vessel panel model in MOSES: Starboard view

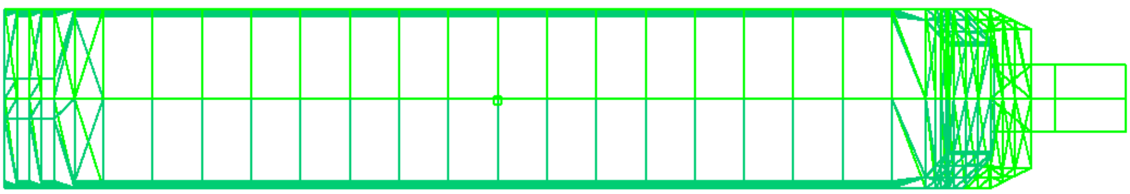

Figure 3-7 Vessel panel model in MOSES: Top view

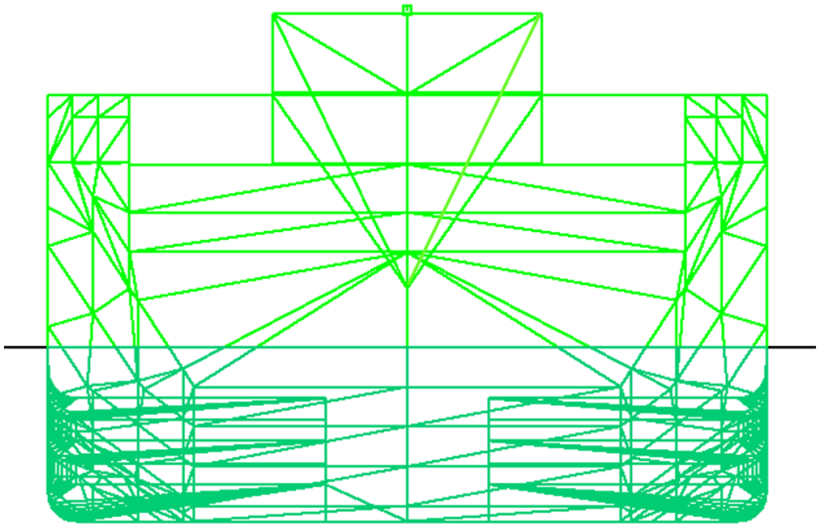

Figure 3-8 Vessel panel model in MOSES: Front view

Generated vessel model need to be validated against actual data. It is important that the model has high level of accuracy to assess the feasibility of the model for further analysis. The acceptable tolerances for hull form dependent refer to ABS MODU, 2012 (See Table 3-8).

Table 3-8 Acceptable tolerances for hull form dependent (ABS MODU, 2012)

Hull form Dependent	**Acceptable tolerance**
Displacement	2%
Longitudinal centre of buoyancy (LCB)	1% / 50cm max
Vertical centre of buoyancy (VCB)	1% / 5cm max
Transverse centre of buoyancy (TCB)	0.5% of *B*/5cm max
Longitudinal centre of floatation (LCF)	1% / 50cm max
Transverse metacentric height (KMt)	1% / 5cm max
Longitudinal metacentric height (KMl)	1% / 50cm max

Table 3-9 shows the comparison results between numerical model and available hydrostatic data. The results show that deviations are within acceptable tolerances, therefore the model is acceptable for further analysis.

Table 3-9 Model verification

Parameter	**Unit**	**Data**	**MOSES**	**Deviation**
Displacement	ton	371020.5	370829.09	0.052%
Longitudinal centre of buoyancy (LCB)	m	191.421	191.34	0.042%
Vertical centre of buoyancy (VCB)	m	7.91	7.91	0.000%
Transverse centre of buoyancy (TCB)	m	0	0	0.000%
Longitudinal centre of floatation (LCF)	m	191.581	191.21	0.194%
Transverse metacentric height (KMt)	m	30.712	30.7	0.039%
Longitudinal metacentric height (KMl)	m	814.754	819.75	0.613%

3.3.2 Wind and Current Load on Vessel

Wind and current load coefficients applied in this analysis obtained from wind tunnel test data performed from previous experiment. Wind and current load coefficients used in this analysis presented in Figure 3-9 and Figure 3-10 respectively. The direction (deg) are relative heading between vessel and wind/current heading, where 0deg is stern-on and 90deg is beam-on from starboard side.

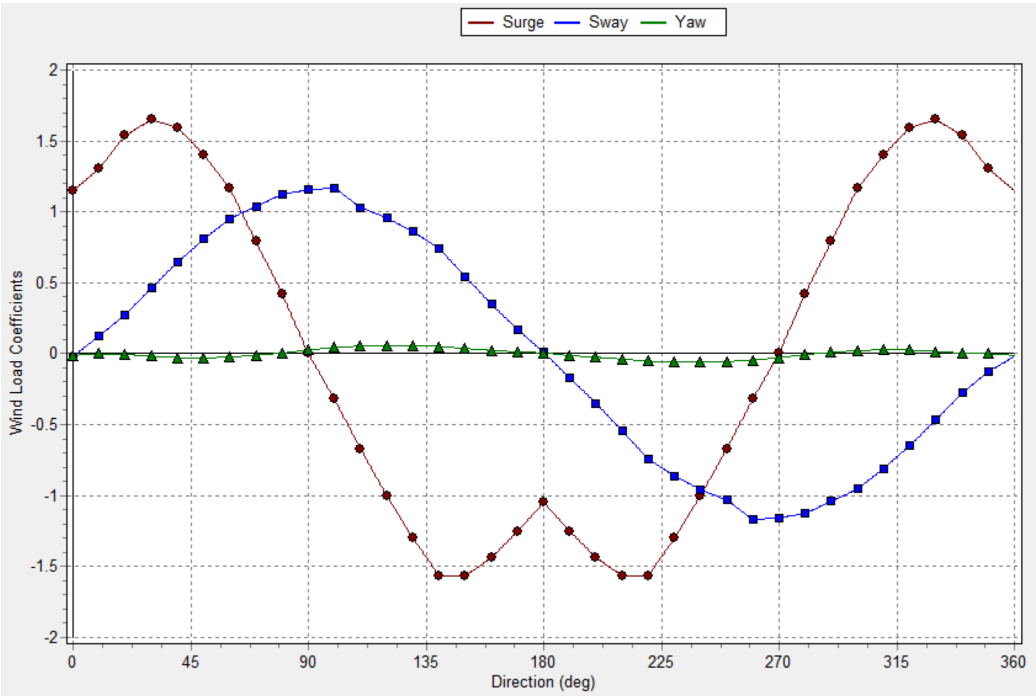

Figure 3-9 Wind load coefficients graph

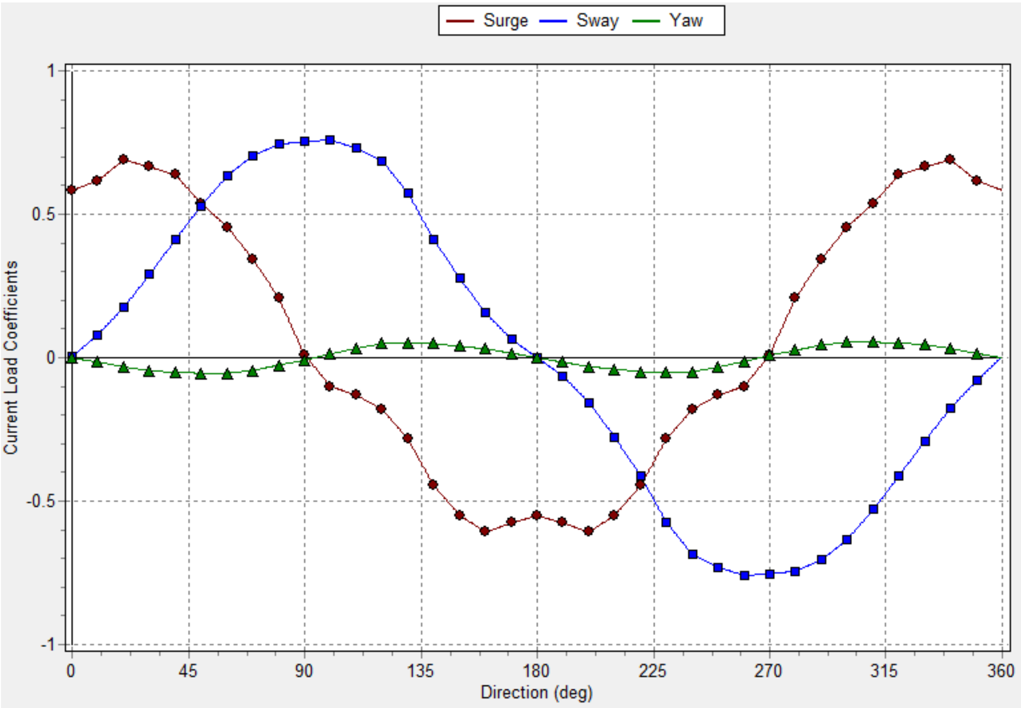

Figure 3-10 Current load coefficients graph

Corresponding value for wind and current coefficient graph above can be found in Table 3-10 and Table 3-11 respectively.

Table 3-10 Wind load coefficients

Direction	Surge	Sway	Yaw
0	1.149	-0.019	-0.011
20	1.539	0.276	-0.004
40	1.594	0.648	-0.027
60	1.165	0.954	-0.023
80	0.425	1.126	0.005
100	-0.320	1.169	0.044
120	-1.000	0.958	0.060
140	-1.564	0.743	0.052
160	-1.438	0.349	0.024
180	-1.049	0.009	0.007
200	-1.438	-0.349	-0.024
220	-1.564	-0.743	-0.052
240	-1.000	-0.958	-0.060
260	-0.320	-1.169	-0.044
280	0.425	-1.126	0.005
300	1.165	-0.954	0.023

Table 3-10 Wind load coefficients (Continued)

Direction	Surge	Sway	Yaw
320	1.594	-0.648	0.027
340	1.539	-0.276	0.004
360	1.149	0.019	0.011

Table 3-11 Current load coefficients

Direction	Surge	Sway	Yaw
0	0.584	0.004	-0.001
20	0.690	0.175	-0.032
40	0.637	0.412	-0.051
60	0.456	0.634	-0.054
80	0.208	0.744	-0.026
100	-0.100	0.759	0.013
120	-0.180	0.686	0.049
140	-0.446	0.412	0.049
160	-0.608	0.156	0.031
180	-0.550	0.000	0.000
200	-0.608	-0.156	-0.031
220	-0.446	-0.412	-0.049
240	-0.180	-0.686	-0.049
260	-0.100	-0.759	-0.013
280	0.208	-0.744	0.026
300	0.456	-0.634	0.054
320	0.637	-0.412	0.051
340	0.690	-0.175	0.032
360	0.584	-0.004	0.001

Wind area applied in numerical calculation are presented in Figure 3-11 and Figure 3-12. Red line represent topside, module, flare tower and turret located on the deck. All structural above the waterline are subjected to wind load thus shall be included in wind area calculation, whereas all structural area below waterline will be subjected to current load and shall be included in current area calculation.

Figure 3-11 Wind area – lateral

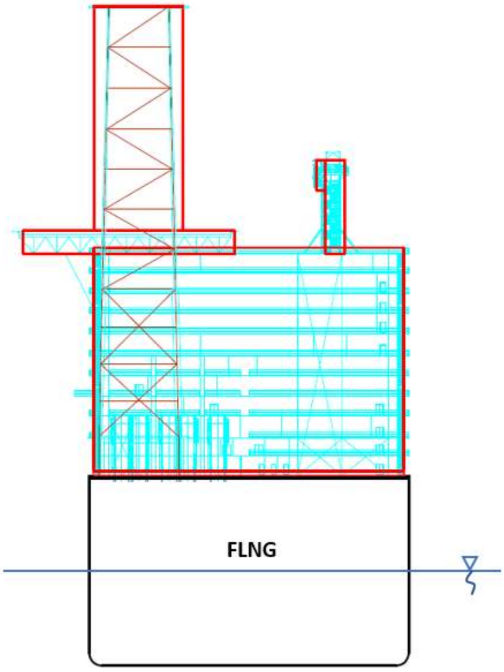

Figure 3-12 Wind area – longitudinal

Based on calculation, total lateral and longitudinal windage area is 27548.43 m^2 and 6697.02 m^2 respectively. Details of windage area calculation are attached in Appendix C.

3.3.3 Mooring System Design

Hydrodynamic properties resulted from MOSES frequency domain simulation (see Section 3.1) is used as vessel data input during vessel and mooring system modelling in OrcaFlex. It is a global static and dynamic analysis program for modelling the behavior of wide variety of marine and offshore systems, typically including boundary condition such as vessels, buoys, as well as finite element modelling of line structures. Time domain dynamic analysis performed to simulate moored vessel under environmental load case. The main purpose of the dynamic analysis is to obtain mooring line tension for various environmental load case. The sign convention utilized for the analysis of motion and loads in earth fixed and vessel fixed local coordinate system are defined below and shown in Figure 3-13.

1) Earth-fixed coordinate system (EFCS):

- The global X axis is coincident with the geographical North.
- The global Y axis is coincident with the geographical West.
- The global Z axis is vertically upwards, with Z=0 at mean water level.

2) Vessel-fixed coordinate system (VFCS):

- The x-axis is along the vessel centerline, with x=0 at FP and positive forward.
- The y-axis is positive towards the port side of the vessel, with y=0 at the FP
- The z-axis is vertically upwards, with z=0 at the vessel keel.

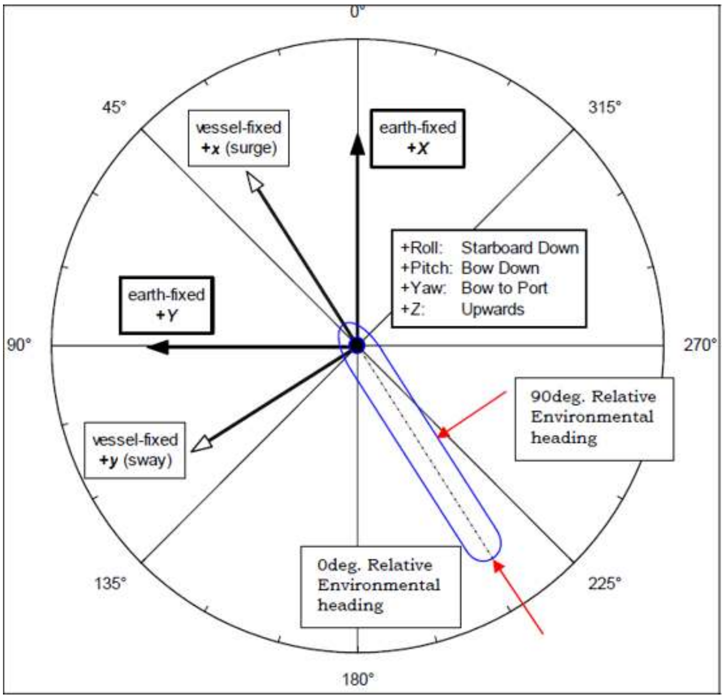

Figure 3-13 Coordinate system

Note that plan view angles increase in a counter-clockwise (CCW) fashion. Unless otherwise noted, both in the analysis and presentation of results, wind, wave and current angles refer to the directions towards which these environments propagate (i.e. heading) in the present EFCS system. Additionally, a relative wave heading of 0deg corresponds to waves approaching the vessel stern-on, while a relative wave heading of 90deg corresponds to waves approaching the vessel on the starboard beam. The model of vessel with its mooring system presented in Figure 3-14 to Figure 3-16.

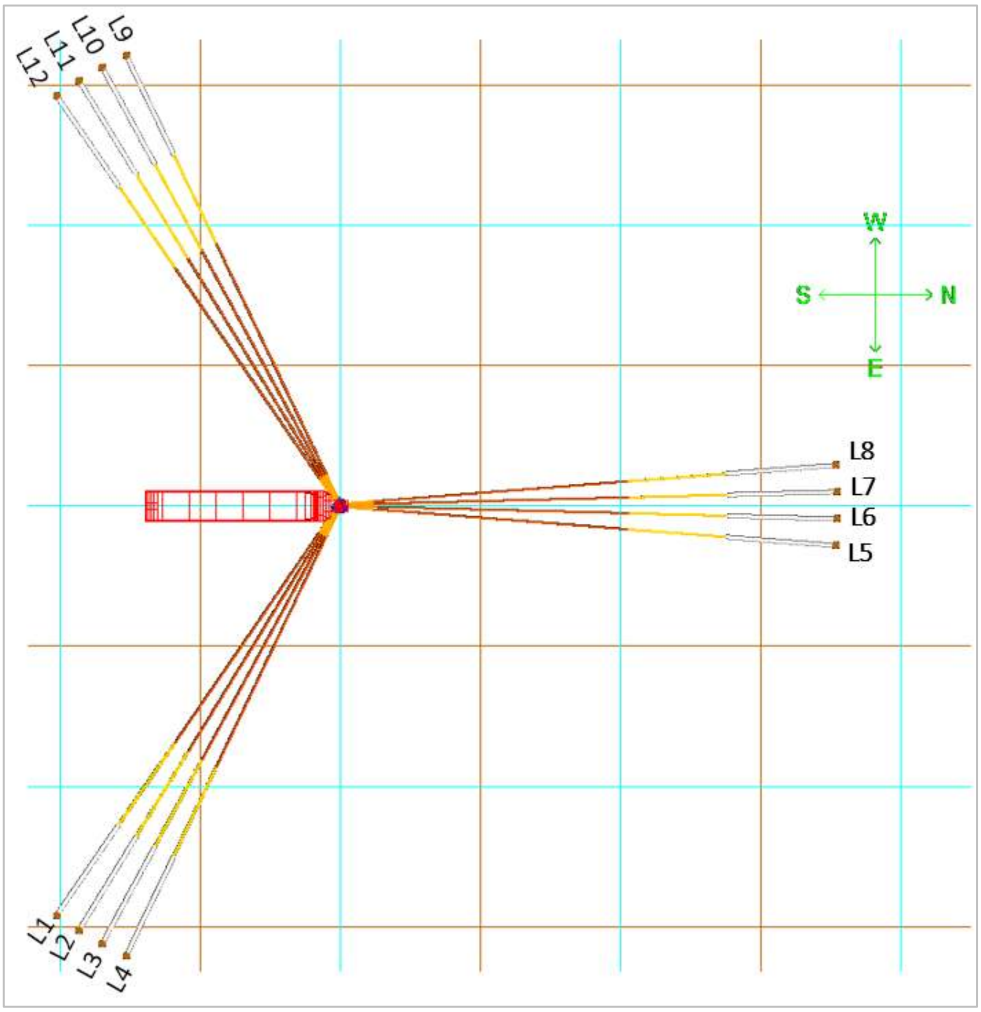

Figure 3-14 Mooring system model in OrcaFlex – Plan view

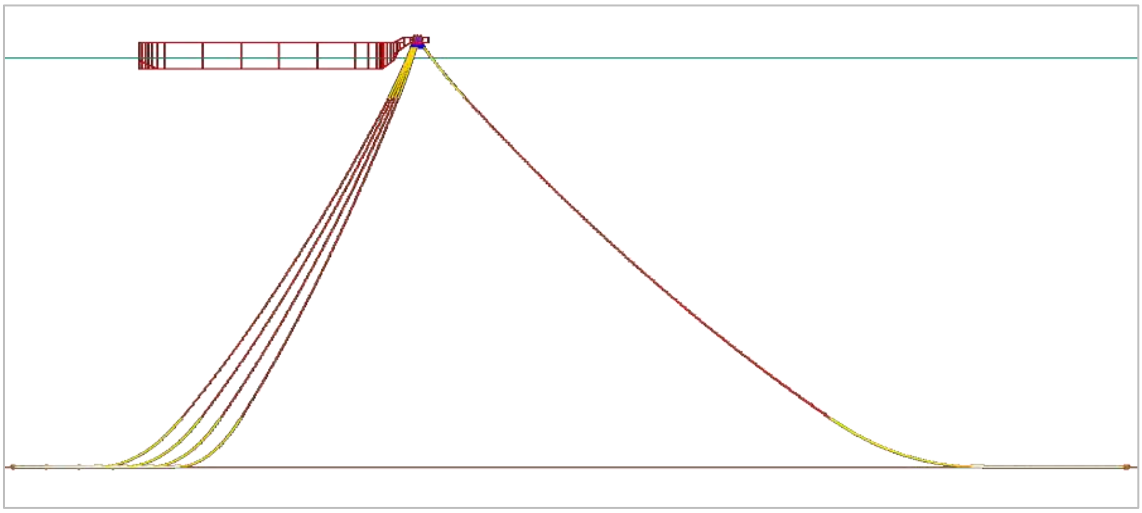

Figure 3-15 Mooring system model in OrcaFlex – Elevation view

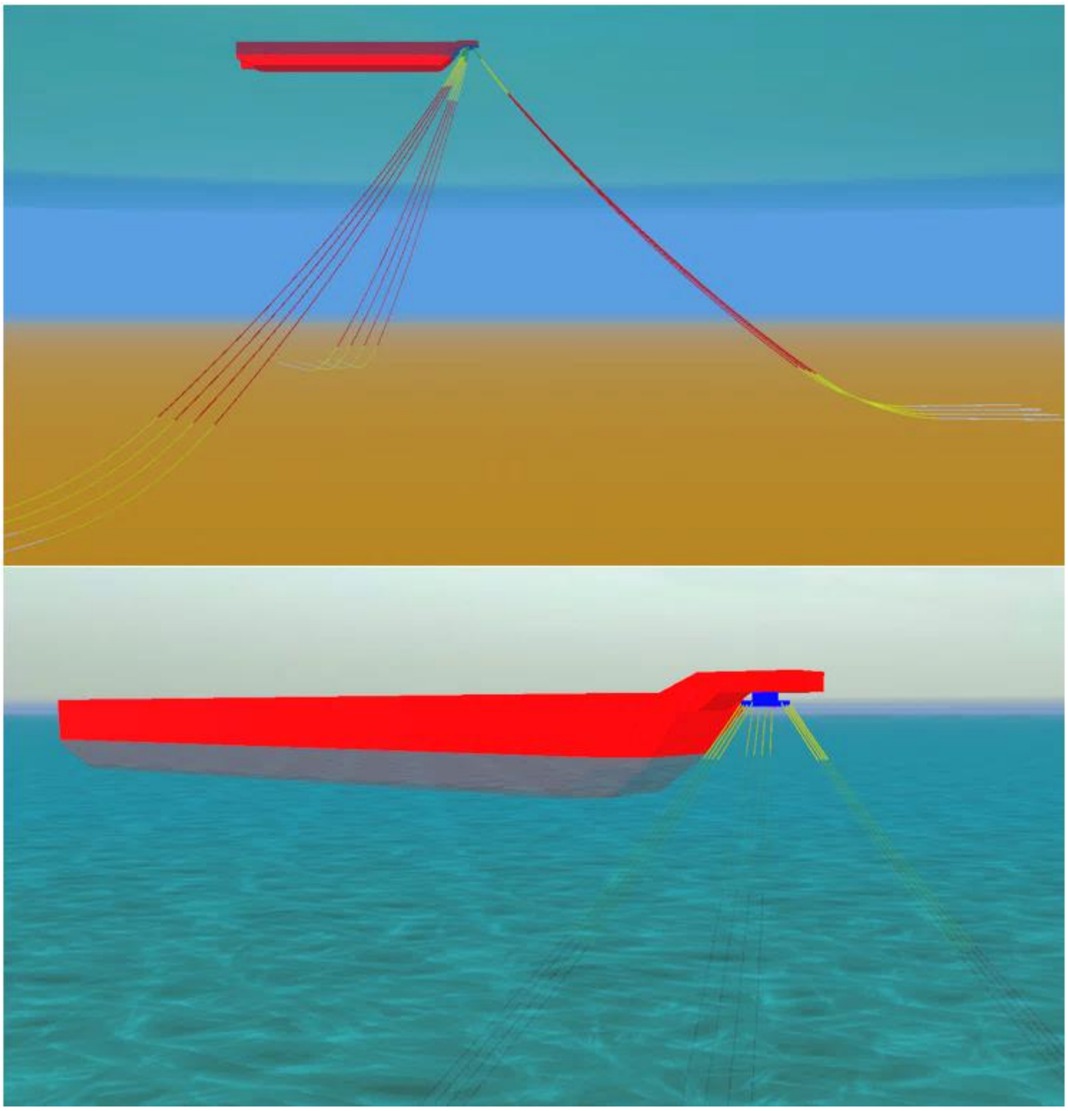

Figure 3-16 Mooring system model in OrcaFlex: Isometric 3D view

3.3.4 Loading Scenario

Moored vessel in initial position as per Figure 3-14 will be subjected to wave, wind and current propagate from the same direction (collinear). Wave and wind data as well as current speed data has been mentioned in previous section (see Section 3.2.2). Each magnitude of wave and wind at certain direction will represent one load cases. Static and dynamic time domain analysis will be performed per load cases. Total 83 load cases are established for each case study. The list of fatigue sea states is reflected in Appendix D.

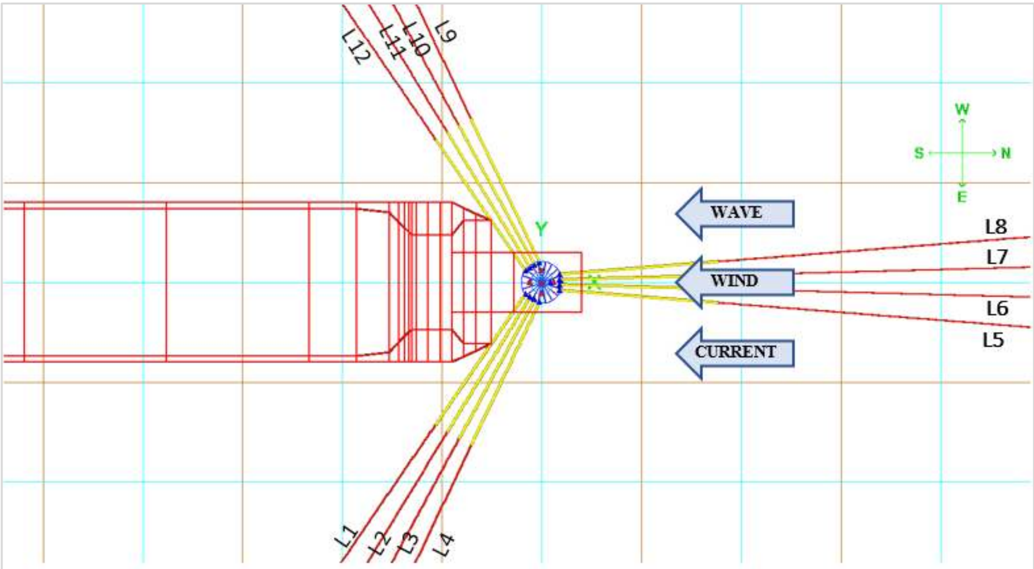

Figure 3-17 Collinear environmental load

As stated in previously, there will be seven case studies (see Table 3-1) in this parametric study, which each of the case study will perform 83 dynamic simulation as per the number of load cases. The global analysis performed for the fatigue analysis can be summarized in Table 3-12 below.

Table 3-12 Fatigue loading condition

	Fatigue analysis
Environment	Long-term operational condition (83 load cases)
Reference direction	8 direction
Environment load	collinear
Vessel loading condition	Operating (draft 15.5m)
Mooring system	Intact condition

4. RESULTS AND DISCUSSIONS

In this section, the results of numerical analysis are presented. The focus here is on fatigue life study of mooring lines. The results of dynamic response, such as: vessel response, mooring line loads and vessel offsets are given as additional information.

4.1 Vessel Hydrodynamic Analysis

Vessel hydrodynamic analysis were performed using MOSES software. Frequency domain-based analysis will generate hydrostatic and hydrodynamic characteristic of free floating vessel, i.e. displacement, buoyancy, added mass and damping, response amplitude operator (RAO) of motion, mean drift forces and linearized wave frequency forces. Analysis carried out under vessel's operating draft condition, T=15.5m, which is required condition for fatigue analysis.

Wetted surface of vessel consists of 1238 panels. The roll axis for the vessel is the X-axis. It is oriented along the centerline of the vessel, running forward and afterward. Longitudinal dimensions are measured along or parallel to this axis. The pitch axis is the Y-axis. It runs transversely port and starboard. Besides being the axis for pitch, transverse dimensions are measured along or parallel to this axis. The yaw axis is the Z-axis. It runs vertically and dimensions are measured along or parallel to this axis.

RAO for six degree of freedom of the free-floating vessel in regular wave shown in Figure 4-1 to Figure 4-6. The RAO's are given with respect to vessel center of gravity. Surge, sway, and heave motions are described per unit wave amplitude, and roll, pitch, and yaw are described per unit wave slope.

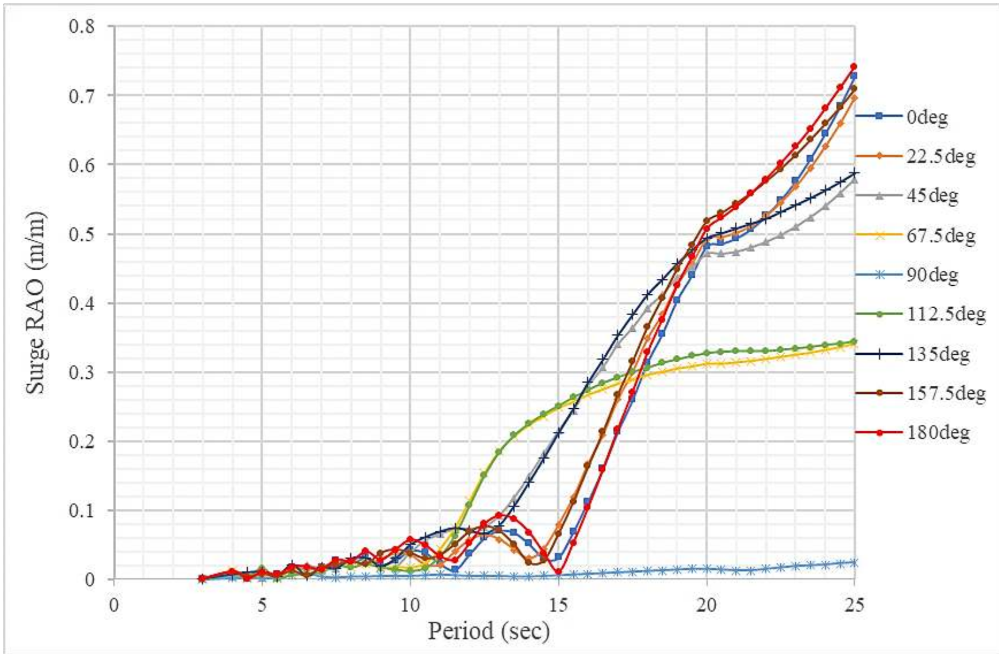

Figure 4-1 Vessel motion operator: Surge

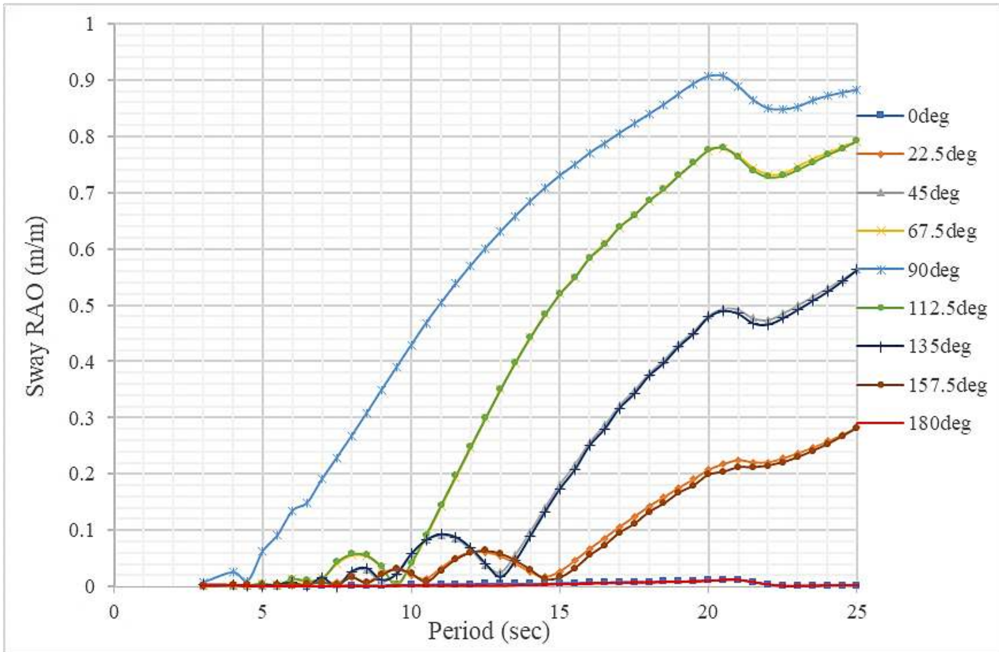

Figure 4-2 Vessel motion operator: Sway

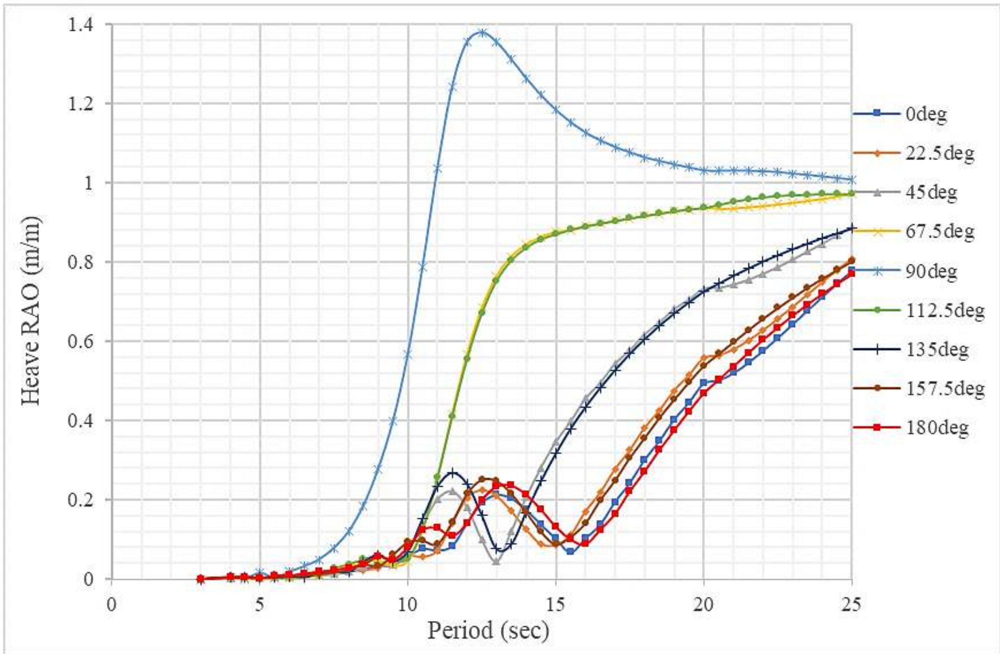

Figure 4-3 Vessel motion operator: Heave

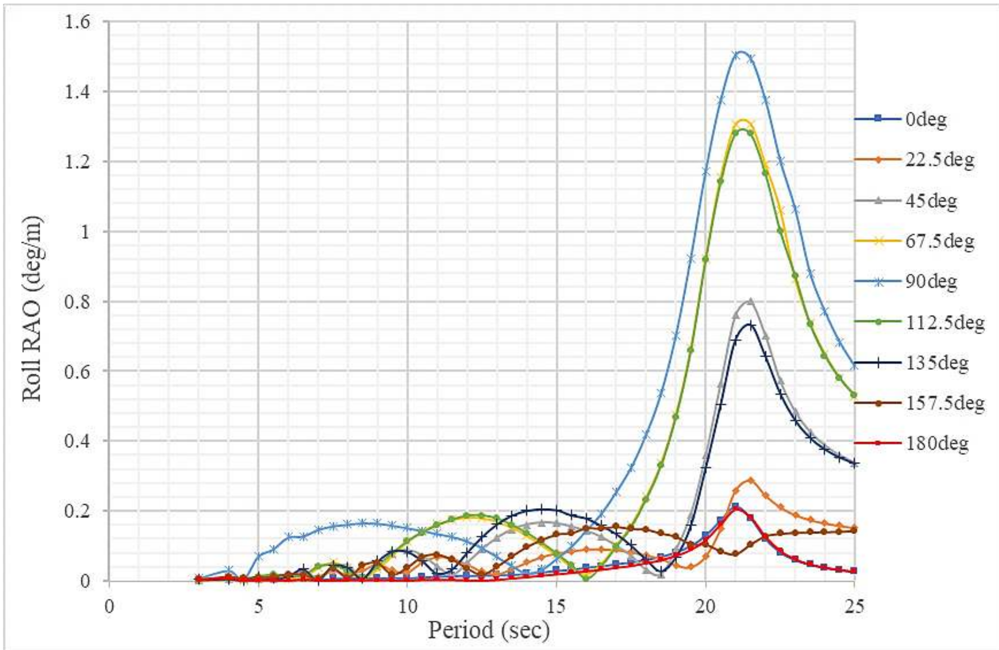

Figure 4-4 Vessel motion operator: Roll

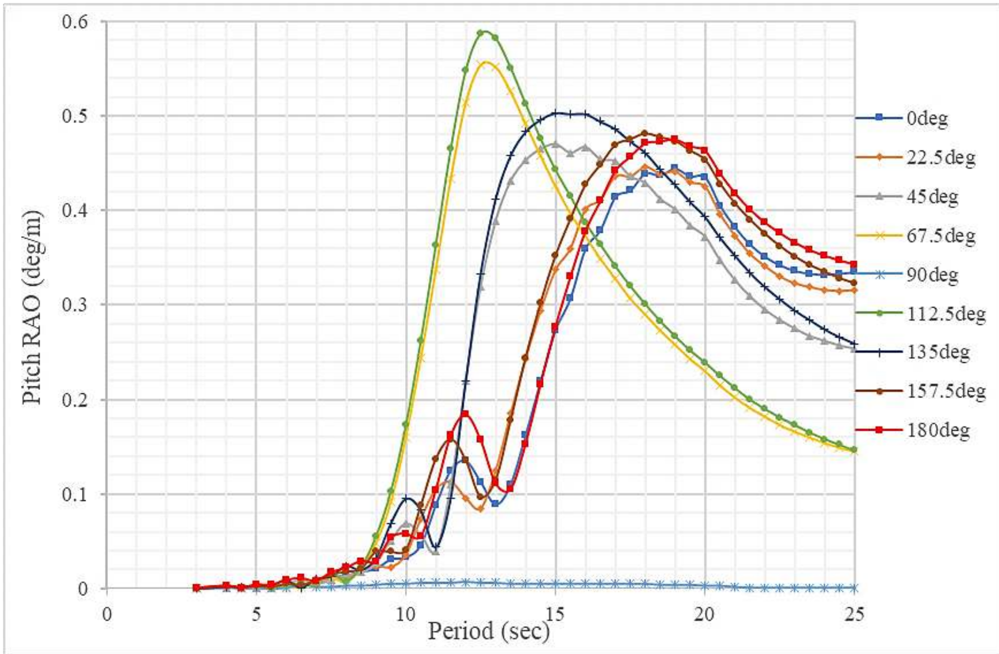

Figure 4-5 Vessel motion operator: Pitch

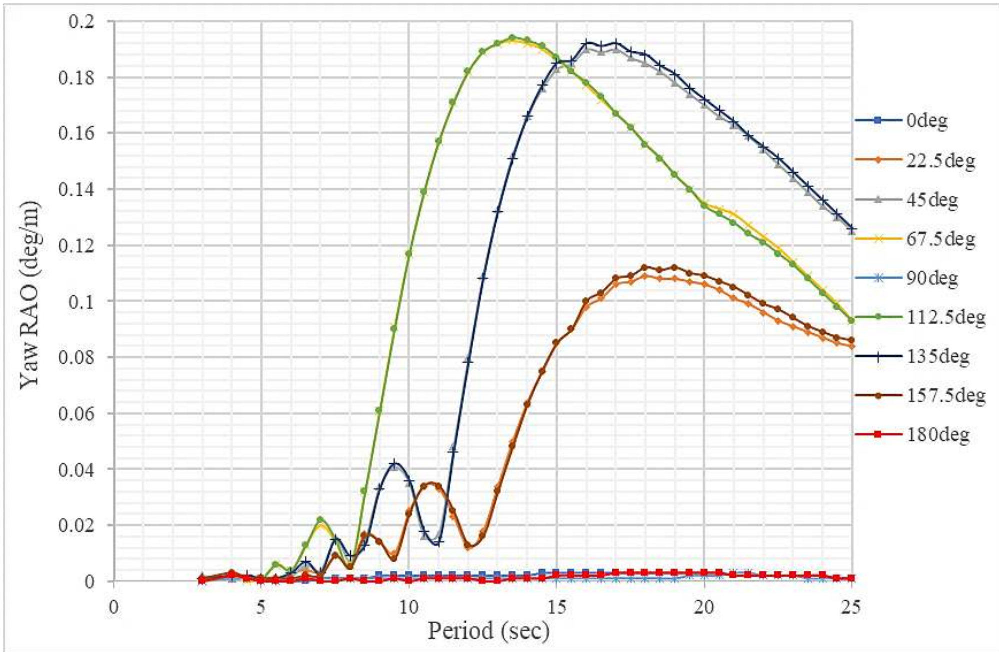

Figure 4-6 Vessel motion operator: Yaw

Highest surge response occurs from head sea (180deg) with RAO max of 0.75 at period of 25sec, which is considered as natural period of surge. While, the smallest response occurs from beam sea (90deg). Conversely, highest sway response occurs from beam sea (90deg) with RAO max of 0.9 at period of 20sec, while the lowest occurs from following and head sea (0deg and 180deg respectively). In higher period, response curve in surge and sway will increase near 1 and for shorter period, the response will decrease gradually. Heave response is highest at beam sea (90deg), where near natural period of 12.5sec the response has peak value around 1.38 and for long waves (long period waves) it becomes 1.

Roll motion has highest response at beam sea, where near natural period of 21sec the response has peak value around 1.5 and for long waves period the response decrease significantly up to 0.6. Pitch motion has peak value around 0.59 at its natural period of 12.5sec and for long wave period, the response decrease gradually up to 0.14.

JONSWAP wave spectrum is chosen in this analysis, as this spectrum is more suitable to be applied in closed water compared another wave spectrum. Furthermore, JONSWAP spectrum has been widely used in the design and analysis of offshore structure operated in Indonesia (Djatmiko, 2012). Calculation of JONSWAP wave spectrum with Hs=1.725m and peakedness parameter γ= 3.3 are plotted in Figure 4-7. Wave spectrum curve for irregular wave with Hs=1.75 and γ= 3.3 has spectra density maximum around 22.5m^2/(rad/sec) at wave period around 12.5sec.

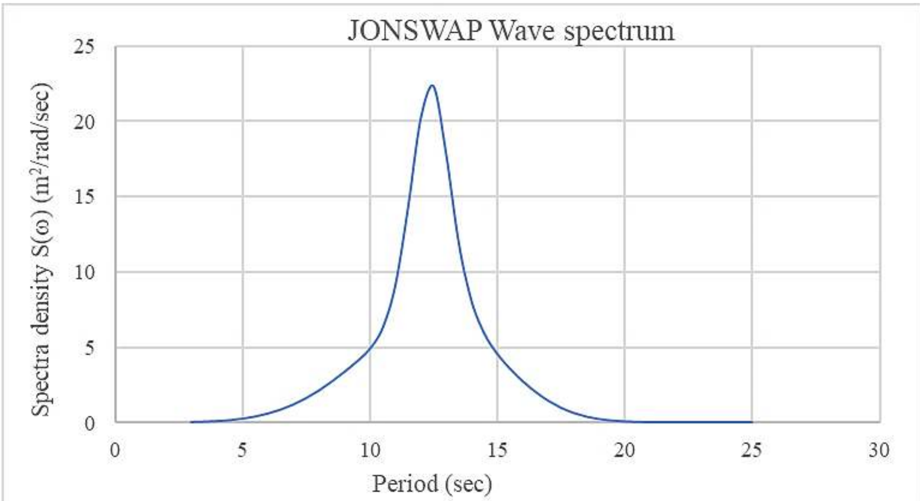

Figure 4-7 Irregular JONSWAP wave spectrum for Hs=1.725m

Surge, Sway, Heave, Roll, Pitch, Yaw QTF and added mass-damping are provided in Appendix B.

4.2 Mooring Line Loads

Mooring lines tension are obtained from time domain based dynamic analysis in OrcaFlex. Hydrodynamic properties resulted from frequency domain analysis will be used as input for dynamic analysis of moored vessel. Time domain dynamic analysis performed by simulating moored vessel in irregular wave with environmental loads stated in Section 3.2.2.

The simulation of moored vessel starts with static analysis, which intended to determine the equilibrium configuration of the system (under; weight, buoyancy, hydrodynamic drag, etc.) and provide starting configuration for dynamic simulation. The load to be taken into account in static analysis are steady current, wind and mean wave drift load. Once static equilibrium has been achieved, followed by dynamic analysis to obtain mooring line tension for each load cases. It is worth mentioning that the analysis performed at intact condition.

4.2.1 Pretension Case

Base case or case study 1 is a benchmark, which will be used as reference to comparing the results of other case studies. The characteristic of moored vessel in this case study is presented in Table 4-1.

Table 4-1 Base case mooring properties

Description	Unit	Case study 1
Pretension	kN	3385 (18% MBL)
Water depth	m	602 (100%water depth)
Wave load type	-	Combined (1st & 2nd order)
Top chain length	m	100.0
Wire rope length	m	725.0
Bottom chain length	m	458.0
Anchor line radius	m	1057.2

Moored vessel properties for the pretension case are summarized in Table 4-2.

Table 4-2 Pretension case mooring properties

Description	Unit	Case Study 2	Case Study 3
Pretension	kN	2600 (14% MBL)	4040 (22% MBL)
Water depth	m	602	602
Wave load type	-	Combined (1st & 2nd order)	Combined (1st & 2nd order)
Top chain length	m	123.8	86.6
Wire rope length	m	725.0	725.0
Bottom chain length	m	458.0	458.0
Anchor line radius	m	1057.2	1057.2

Mooring line tension and turret offset results from vessel global analysis for pretension case are presented in Table 4-3. The results are summarized for highest tension from all calculated load case. Most tensioned line occurred at line 6 under load case no.77 with Hs=1.725m; Tp=6.35m; V_w=14.85m/s; V_c=0.68m/s where the environmental loads are in-line with one mooring group (head sea).

Table 4-3 Mooring line load – Pretension case

	Tension (kN)	Max. offset radius (m) – from zero position
Case study 1	3898.7	13.3
Case study 2	3128.6	21.3
Case study 3	4437.8	9.7

Case study 3 with pretension of 22% MBL, yields highest line tension of 4437.8kN followed with case study 1 and case study 2 with line tension of 3898.7kN and 3128.6kN respectively. All the highest line tension occurred at fairlead point (top chain segment). An increase in pretension for 4% will increase the dynamic line tension by 14% from initial dynamic tension, while a 4% decrease of pretension will reduce the dynamic line tension by 20% from initial dynamic tension.

The vessel experienced maximum horizontal excursion of 21.3m for case study 2, followed by case study 1 and case study 3 with 13.3m and 9.7m respectively. An 4% increase in pretension will reduce the horizontal excursion by 37% from its initial excursion, while a 4% decrease of pretension will increase horizontal excursion by 60% from its initial excursion.

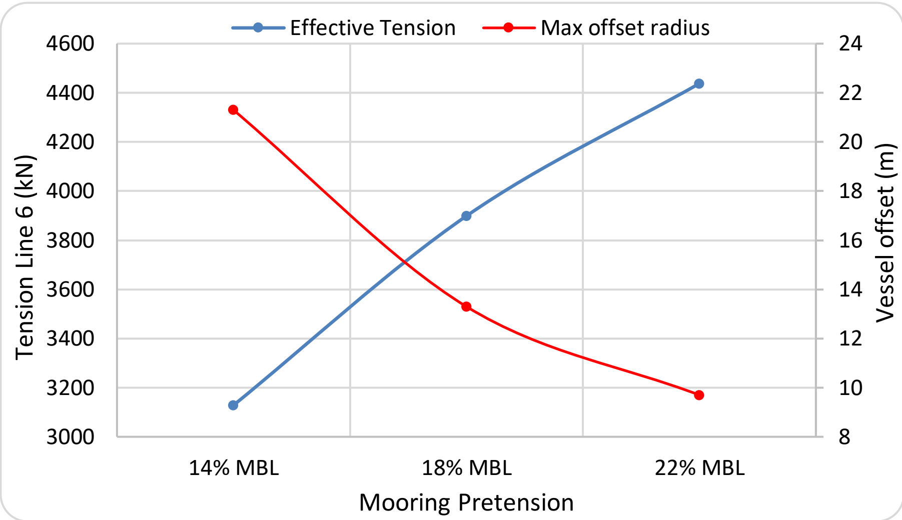

Figure 4-8 Maximum line tension and vessel offset for pretension case

The higher mooring line pretension, will lead to higher dynamic tension of line. On the contrary, the higher mooring line pretension, will reduce vessel offset since the excursion of the vessel will be limited by high restoring force of mooring lines. Figure 4-8 presents the correlation between tension line and vessel offset for different pretension line.

4.2.2 Water Depth Case

Moored vessel properties for the water depth case (case study 4 and 5) are summarized in Table 4-4.

Table 4-4 Water depth case mooring properties

Description	Unit	Case Study 4	Case Study 5
Pretension	kN	2030	4764
Water depth	m	301 (50%WD)	903 (150%WD)
Wave load type	-	Combined (1st & 2nd order)	Combined (1st & 2nd order)
Top chain length	m	50.0	150.0
Wire rope length	m	362.5	1087.5
Bottom chain length	m	229.0	687.0
Anchor line radius	m	528.6	1585.8

Mooring line tension and turret offset results from vessel global analysis for water depth case are presented in Table 4-5. The results are summarized for highest tension from all calculated load case. Most tensioned line occurred at line 6 under load case no.77 with Hs=1.725m; Tp=6.35m; V_w=14.85m/s; V_c=0.68m/s where the environmental loads are in-line with one mooring group (head sea).

Table 4-5 Mooring line load – water depth case

	Tension (kN)	Max. offset radius (m) – from zero position
Case study 1	3898.7	13.3
Case study 4	2432.3	10.1
Case study 5	5198.1	13.5

Case study 5 with water depth 150% of initial water depth, yields highest line tension of 5198.1kN followed with case study 1 and case study 4 with line tension of 3898.7kN and 2432.3kN respectively. An increase in water depth for 50% will increase the dynamic line tension by 33% from initial dynamic tension, while a 50% decrease of water depth will reduce the dynamic line tension by 38% from initial dynamic tension.

The vessel experienced maximum horizontal excursion of 13.5m for case study 5, followed by case study 1 and case study 4 with 13.3m and 10.1m respectively. An increase in water depth for 50% will increase the horizontal excursion by 2% from its initial excursion, while a 50% decrease of water depth will decrease the horizontal excursion by 24% from its initial excursion.

The higher water depth will increase the mooring line length that lead to the increase of its weight. The increase in mooring line length will give additional drag force on the line that leads to higher tension on the line. The increase on the weight of mooring line will increase the pretension. As discussed previously, the increase in pretension will leads to higher dynamic tension on the line. Figure 4-9 presents the correlation between tension line and water depth change.

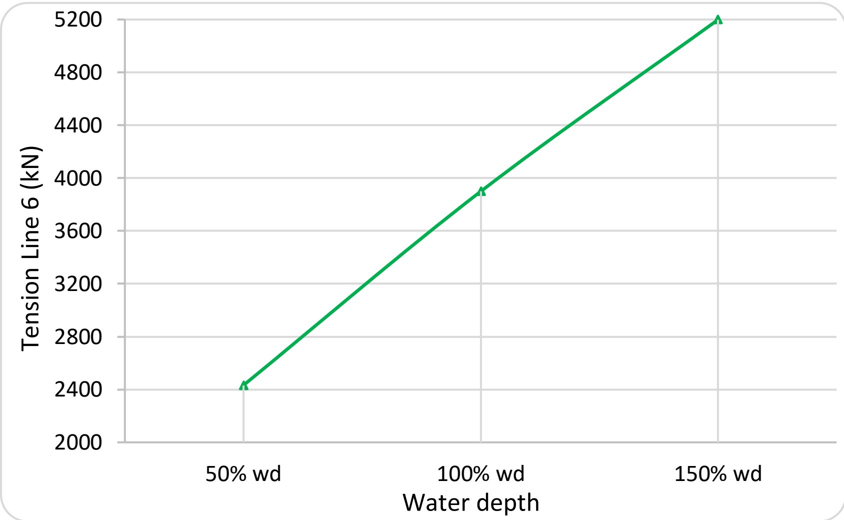

Figure 4-9 Maximum tension of Line 6 for water depth case

4.2.3 Wave Load Type

Moored vessel properties for the wave load type case (case study 6 and 7) are summarized in Table 4-6.

Table 4-6 Wave load type mooring properties

Description	Unit	Case Study 6	Case Study 7
Pretension	kN	3385	3385
Water depth	m	602	602
Wave load type	-	1st order	2nd order
Top chain length	m	100.0	100.0
Wire rope length	m	725.0	725.0

Table 4-6 Wave load type mooring properties (Continued)

Description	Unit	Case Study 6	Case Study 7
Bottom chain length	m	458.0	458.0
Anchor line radius	m	1057.2	1057.2

Mooring line tension and turret offset results from vessel global analysis for wave load type case are presented in Table 4-7. The results are summarized for highest tension from all calculated load case. Most tensioned line occurred at line 6 under load case no.77 with Hs=1.725m; Tp=6.35m; V_w=14.85m/s; V_c=0.68m/s where the environmental loads are in-line with one mooring group (head sea).

Table 4-7 Mooring line load – wave load type case

	Tension (kN)	Max. offset radius (m) – from zero position
Case study 1	3898.7	13.3
Case study 6	3702.5	8.3
Case study 7	3802.4	12.2

Case study 1 with combined 1st order and 2nd order wave load yields highest line tension of 3898.7kN followed with case study 7 and case study 6 with line tension of 3802.4kN and 3702.5kN respectively. It is generally agreed that 1st order wave load has less contribution to the tension of mooring line compared to 2nd order wave load, thus the results above have good agreement with that statement.

The vessel experienced maximum horizontal excursion of 13.3m for case study 1, followed by case study 7 and case study 6 with horizontal excursion of 12.2m and 8.3m respectively. In line with the tension results, the 1st order wave load has less contribution to the excursion of moored structure compared to 2nd order wave load, where the 2nd order wave load yields higher radius vessel offset than 1st order wave load.

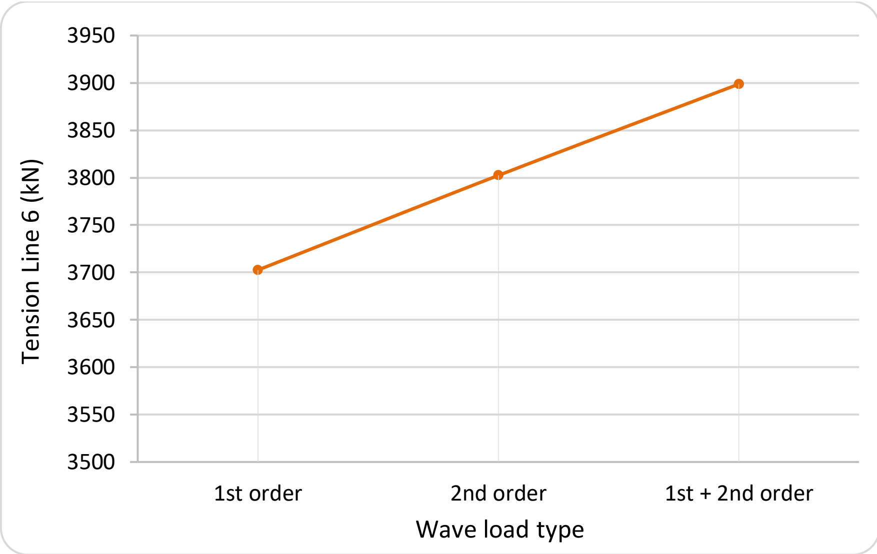

Figure 4-10 Maximum tension of Line 6 for wave load type case

Floating unit normally experience significant LF response in the horizontal plane and may be particularly sensitive to surge excitation due to the low viscous hull damping (DNV-RP-F205, 2010). Compared to 1st order wave forces, the 2nd order wave forces give smaller value and have no significant effect on vertical motion (heave, roll, pitch) where hydrostatic restoring force are established. However, for the horizontal motion (surge, sway, yaw) where the restoring forces arise due to mooring lines, the motion of 2nd order wave forces are quite significant. This affects the offset radius, where 2nd order wave component gives higher horizontal vessel offset than 1st order wave component. The higher vessel offset will increase line restoring force that lead to higher dynamic tension on the line. Figure 4-10 presents the correlation between tension line and wave load component.

4.3 Mooring Line Fatigue Life

Tension fatigue analysis is performed to estimate the fatigue life of the major mooring components, such as top chain, steel wire and bottom chain. It is worth mentioning that the T-N curve of steel wire is significantly less severe than the T-N curve of mooring chain (Refer to Section 2.2.9). Consequently, for similar tension range the damage caused in the mooring chain is significantly higher. Therefore, the critical components in this mooring system are the chain segments.

As mentioned in previous section, the fatigue analysis is performed using the results of time domain analysis and the cyclic of tension are computed using Rainflow counting method. The estimates fatigue life for each mooring line are selected conservatively as the minimum estimated life from all fatigue load cases.

4.3.1 Base Case

Base case or case study 1 is selected to be the control case. This case represents actual condition of moored FLNG as per existing data mentioned in Section 3.3. The summary results of fatigue analysis for base case is provided in Table 4-8. In this table, the expected life of mooring components, i.e. top chain, steel wire and bottom chain of all 12 mooring lines are presented. The factor of safety (FoS) in this table is estimated as the ratio of the expected life by the design life of the system (30 year).

Table 4-8 Summary of base case fatigue analysis

Line No.	Line Section	Damage	Life (year)	FoS
Line 1	Top chain	1.8E-04	5568.91	185.6
	Steel wire	4.96E-08	20159058.10	671968.6
	Bottom chain	2.18E-04	4602.76	153.4
Line 2	Top chain	1.84E-04	5448.56	181.6
	Steel wire	4.95E-08	20218888.70	673963.0
	Bottom chain	2.20E-04	4547.26	151.6
Line 3	Top chain	1.88E-04	5329.70	177.7
	Steel wire	5.02E-08	19938695.70	664623.2
	Bottom chain	2.23E-04	4485.81	149.5
Line 4	Top chain	1.94E-04	5165.53	172.2
	Steel wire	5.17E-08	19359285.55	645309.5
	Bottom chain	2.30E-04	4344.83	144.8

Table 4-8 Summary of base case fatigue analysis (Continued)

Line No.	Line Section	Damage	Life (year)	FoS
Line 5	Top chain	3.13E-04	3191.51	106.4
	Steel wire	7.04E-08	14194558.87	473152.0
	Bottom chain	3.35E-04	2983.33	99.4
Line 6	Top chain	2.97E-04	3363.14	112.1
	Steel wire	6.49E-08	15409427.82	513647.6
	Bottom chain	3.14E-04	3182.19	106.1
Line 7	Top chain	2.85E-04	3508.40	116.9
	Steel wire	5.96E-08	16774249.90	559141.7
	Bottom chain	2.94E-04	3405.18	113.5
Line 8	Top chain	2.77E-04	3614.95	120.5
	Steel wire	5.47E-08	18265933.00	608864.4
	Bottom chain	2.73E-04	3663.54	122.1
Line 9	Top chain	2.24E-04	4473.85	149.1
	Steel wire	5.87E-08	17031388.29	567712.9
	Bottom chain	2.74E-04	3651.18	121.7
Line 10	Top chain	2.35E-04	4259.62	142.0
	Steel wire	6.25E-08	16006118.87	533537.3
	Bottom chain	2.86E-04	3491.00	116.4
Line 11	Top chain	2.44E-04	4092.07	136.4
	Steel wire	6.61E-08	15136901.28	504563.4
	Bottom chain	2.99E-04	3345.88	111.5
Line 12	Top chain	2.54E-04	3942.10	131.4
	Steel wire	7.00E-08	14290144.69	476338.2
	Bottom chain	3.13E-04	3199.55	106.7

As seen in Table 4-8, fatigue life of top and bottom chain is significantly shorter than steel wire. The most severe fatigue life, 2983.33 years, occurs on mooring line 5 at bottom chain section (approx. arc length 826m). The minimum FoS is 99.4 which is higher than required value of 3 from API RP 2SK. Furthermore, top chain section of Line 5 also has minimum fatigue life compare to another line at the same section, with estimated value 3191.51 years. Fatigue life at line 5 along the arc length presented in Figure 4-11.

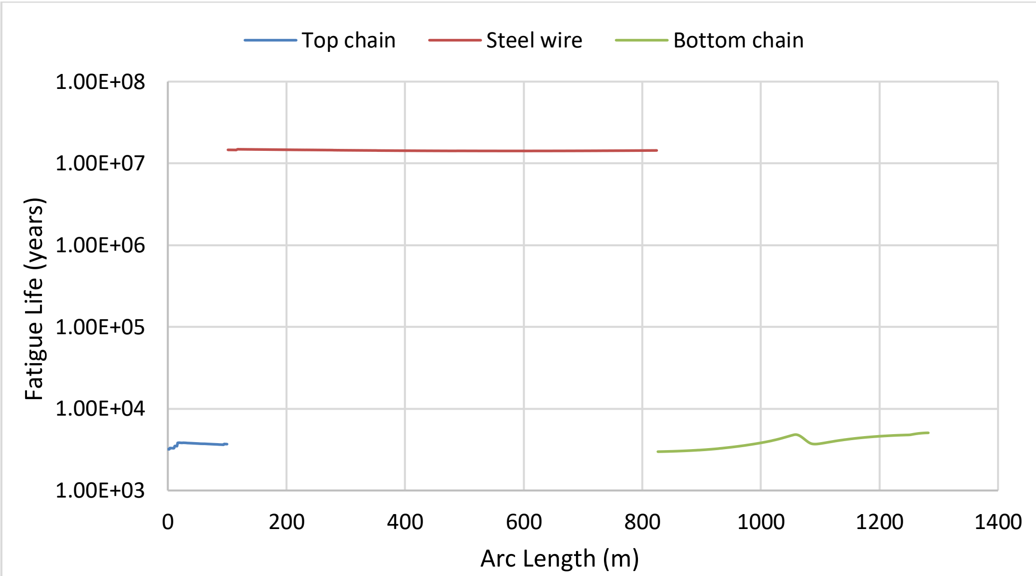

Figure 4-11 Fatigue life graph at Line 5

Bottom chain section (at arc length 826m) has higher tension range compare to top chain section (at arc length 0m), which is characterized by line tension standard deviation (STD). Bottom chain section (at arc length 826m) has higher STD of 43.89, while top chain section (at arc length 0m) has STD of 41.3. Furthermore, bottom chain section's material has smaller MBL with 17,317kN compare to top chain section's material with MBL of 18,496kN. This will affect the ratio of tension range to reference breaking strength, *R*, in the API T-N curve of mooring chain (see Section 2.2.9). Assumed for fixed value of tension range, then the bottom chain section has higher ratio *R* than top chain section. This will lead to lower value of *N* (number of cycles to failure), where the lower value of *N* will reduce the fatigue life. Tension comparison of Line 5 at different chain section presented in Figure 4-12.

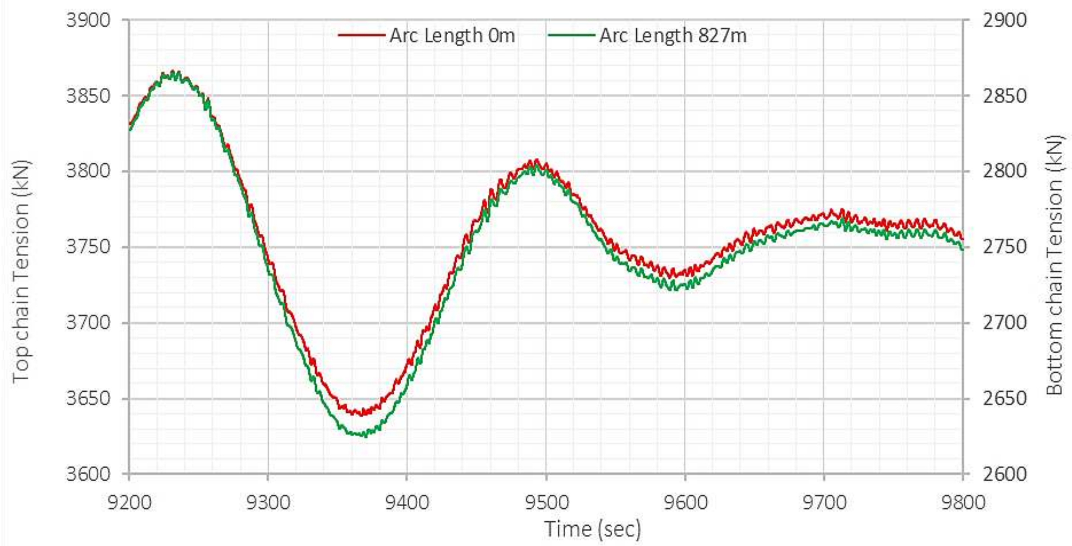

Figure 4-12 Tension comparison of Line 5 at arc length 0m vs 826m. Load case 77 with Hs=1.725m; Tp=6.35m; V_w=14.85m/s; V_c=0.68m/s; μ=180^o collinear

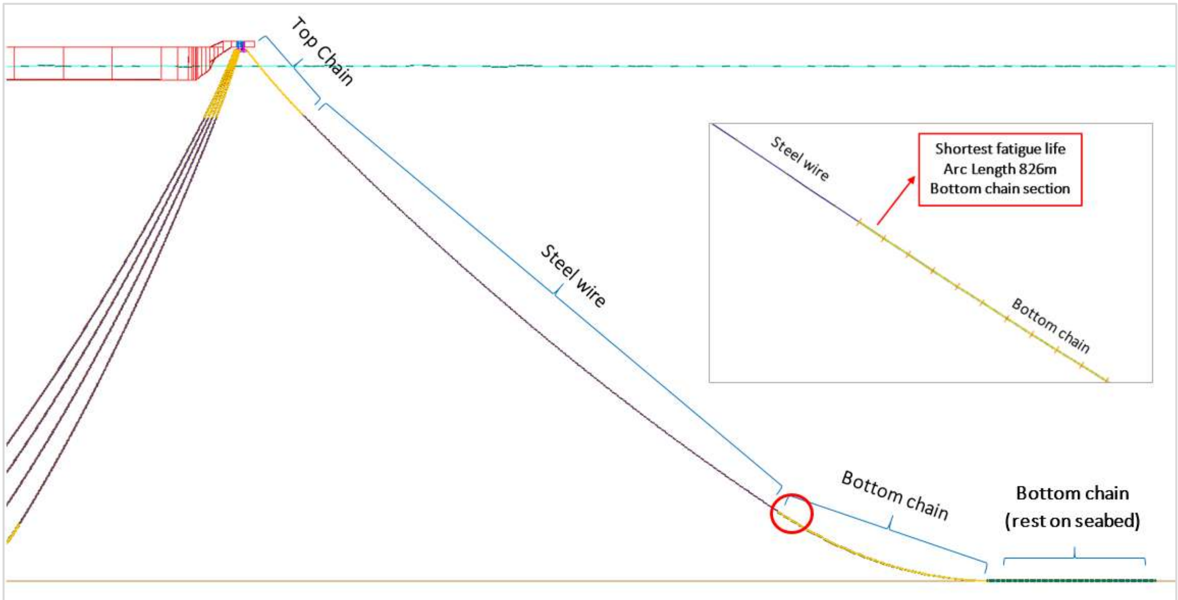

Figure 4-13 Line section with shortest fatigue life – Line 5

4.3.2 Mooring Pretension Case

The main purpose of mooring system is to provide seakeeping and maintain floating structure on position within specific tolerance, typically based on offset limit. The offset limit can be varying for various system depends on riser configuration, well position, the existence of another facility in the vicinity of the structure, etc. To provide desirable vessel offset, one can adjust the pretension on mooring system. Hence, the determination of pretension value has important role in the operation of mooring system. To investigate the influence of mooring line pretension on the fatigue life, case study 1, 2 and 3 with different pretension are specified. Summary results of fatigue life for case study 2 (14%MBL of pretension) and case study 3 (22%MBL of pretension) provided in Appendix E.

A comparison between the results of fatigue base case and pretension case are presented in Figure 4-14.

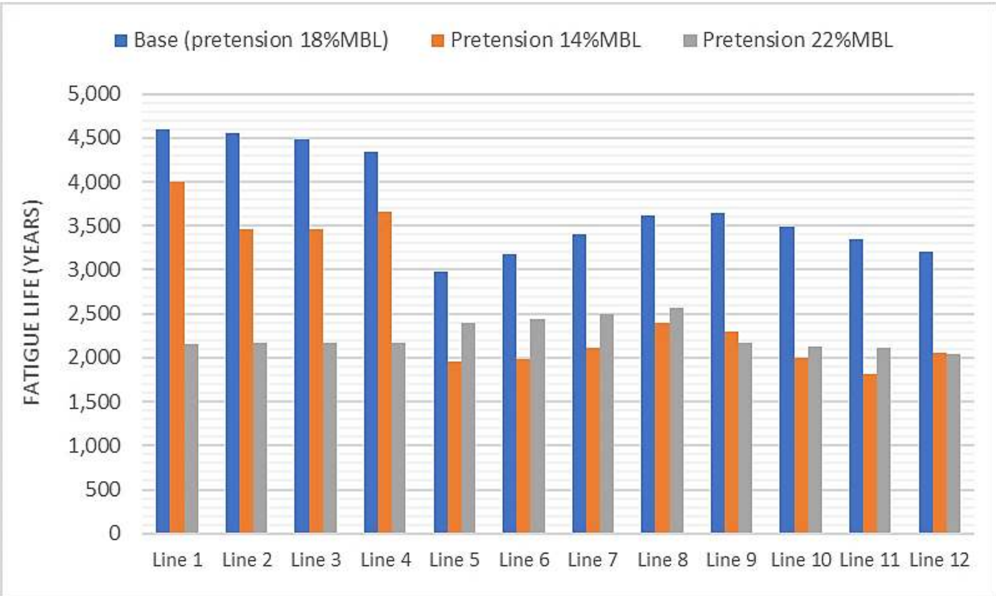

Figure 4-14 Mooring line fatigue life for cases with different pretension

It is seen from Figure 4-14 that base case (18%MBL of pretension) yields much longer fatigue life than case study 2 (14%MBL of pretension) and case study 3 (22%MBL of pretension). Generally, the most critical fatigue life occurs at case study 2, except for line 1 to 4, followed by case study 3 and case study 1 respectively. Case study 2 has the shortest fatigue life of 1814.2 years followed by case study 3 and case study 1 with 2034.61 years and 2983.33 years respectively. Detailed minimum fatigue life for each pretension condition are presented in Table 4-9.

Table 4-9 Minimum fatigue life with different pretension

	Fatigue Life (years)	Fatigue damage
Case study 1	2983.33	3.35E-04
Case study 2	1814.20	5.51E-04
Case study 3	2034.61	4.91E-04

As stated in previous section, dynamic line tension increase with increasing of pretension, therefore it is agreed that case study 2 has the lowest line tension (See Table 4-3). It is interesting to note that, despite has the lowest tension, case study 2 has the highest fatigue damage (shortest fatigue life). Smaller pretension will cause larger vessel offset, since mooring line tend to be in slack position. The larger vessel offset could lead to larger tension range of mooring line during simulation. Tension range distribution during simulation period represented by standard deviation (STD), where a bigger value of STD indicates larger tension distribution. Table 4-10 shows max tension, mean tension and standard deviation (STD) of line tension. Mooring line fatigue life decrease due to the increase in line tension STD as vessel offset increases. Therefore, the determination of pretension will affect the fatigue life of mooring lines during operation.

Table 4-10 Tension statistics for pretension case

	Case study 1	Case study 2	Case study 3
Max tension (kN)	3898.70	3128.60	4437.80
Mean tension (kN)	3392.77	2554.76	3971.93
STD	50.58	52.09	51.23

4.3.3 Water Depth Case

Water depth is recognized as one of important parameter in mooring system design. It will affect mooring line length, material and configuration. In order to investigate the effect of water depth on the mooring line tension and fatigue damage, dynamic analysis of case study 1, 4 and 5 are performed. Water depth are 301m, 602m and 903m in case study 4, 1 and 5 respectively. The water depth of case study 4 is half (50%) of case study 1, while case study 5 has water depth 1.5 (150%) of case study 1. Summary results of fatigue life for case study 4 and case study 5 provided in Appendix E.

Comparison results of fatigue base case and water depth case are listed and discussed as follow.

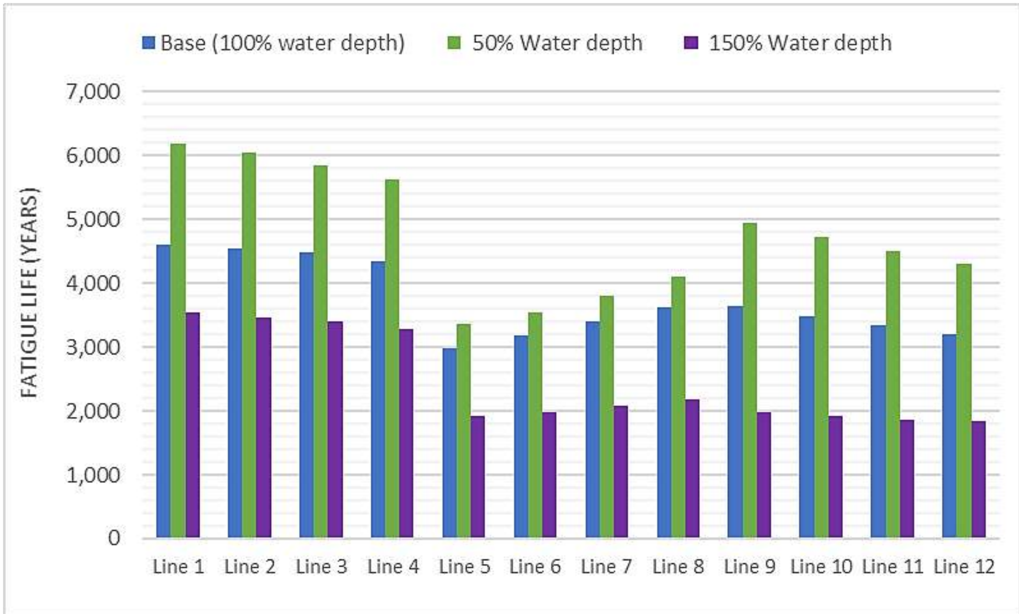

Figure 4-15 Mooring line fatigue life for cases with different water depth

Figure 4-15 shows that the most critical fatigue life for different water depth occurs at case study 5 with 903m water depth. While case study 4 with 301m water depth yields longest fatigue life. Detailed minimum fatigue life for each water depth condition presented in Table 4-11. Case study 5 has shortest fatigue life of 1842.65 years followed by case study 1 and 4 with 2983.33 years and 3363.62 years respectively.

Table 4-11 Minimum fatigue life with different water depth

	Fatigue Life (years)	**Fatigue damage**
Case study 1	2983.33	3.35E-04
Case study 4	3363.62	2.97E-04
Case study 5	1842.65	5.43E-04

As described in Section 4.2.2, in the deeper water depth, the weight of mooring line will increase due to the increases in mooring line length. This increase in length and weight will be followed by increase of drag force and pretension on mooring line, that lead to the increase of effective and mean tension on the mooring lines. Table 4-12 presents tension statistic for water depth case. Case study 5 with shortest fatigue life has highest STD of 56.02, while case study 4 with longest fatigue life has lowest STD of 45.34. This results have good agreement with previous section (pretension case) where the higher STD, means high tension range, will result in shorter fatigue life.

Table 4-12 Tension statistics for water depth case

	Case study 1	**Case study 4**	**Case study 5**
Max tension (kN)	3898.70	2432.30	5198.10
Mean tension (kN)	3392.77	2045.30	4692.69
STD	50.58	45.34	56.02

4.3.4 Wave Load Type Case

As described in previous section, wave load acting on floating structure have 1st order and 2nd order components. The behavior of structure and its mooring line would also be affected by combination of 1st order and 2nd order wave loads. The influence of the 1st order and 2nd order wave loads on moored vessel has been discussed by many researchers, covers the behavior of vessel and tension of mooring lines. To investigate the influence of wave load component on the fatigue life of mooring lines, case study 1, 6 and 7 with different wave load type are specified.

Comparison results of fatigue life for case study 1 (combined: 1st order and 2nd order wave load), case study 6 (1st order wave load) and case study 7 (2nd order wave load) are presented in Figure 4-16 and Table 4-13. Summary results of fatigue life for case study 6 and case study 7 provided in Appendix E.

Figure 4-16 Mooring line fatigue life for cases with different wave load type

In general, 1st order wave load induces shorter mooring fatigue life than 2nd order wave load. Detailed minimum fatigue life for each wave load type case presented in Table 4-13. It is shows that case study 6 has the most critical fatigue life with 1186.71 years, while case study 7 and case study 1 have slightly different fatigue life with 2872.47 years and 2983.33 years respectively.

Table 4-13 Minimum fatigue life with different wave load type

	Fatigue Life (years)	**Fatigue damage**
Case study 1	2983.33	3.35E-04
Case study 6	1186.71	8.43E-04
Case study 7	2872.47	3.48E-04

For the wave load type case, the calculation indicates that line 5 at bottom chain section (approx. arc length 826m) is the most critical fatigue line. Time series of dynamic tension in Line 5 at arc length 826m presented in Figure 4-17 and Figure 4-18, while surge response of moored FLNG for load case 77 with with Hs=1.725m; Tp=6.35m; Vw=14.85m/s; Vc=0.68m/s; μ=180° collinear presented in Figure 4-19 and Figure 4-20.

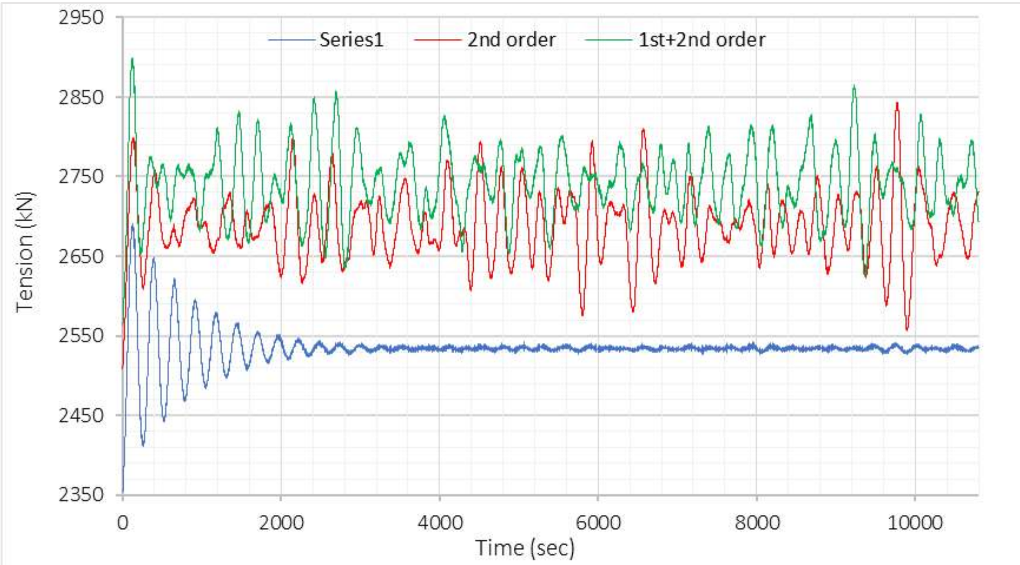

Figure 4-17 Time series of tension in Line 5 - arc length 826m. Load case 77 with Hs=1.725m; Tp=6.35m; V_w=14.85m/s; V_c=0.68m/s; μ=180° collinear

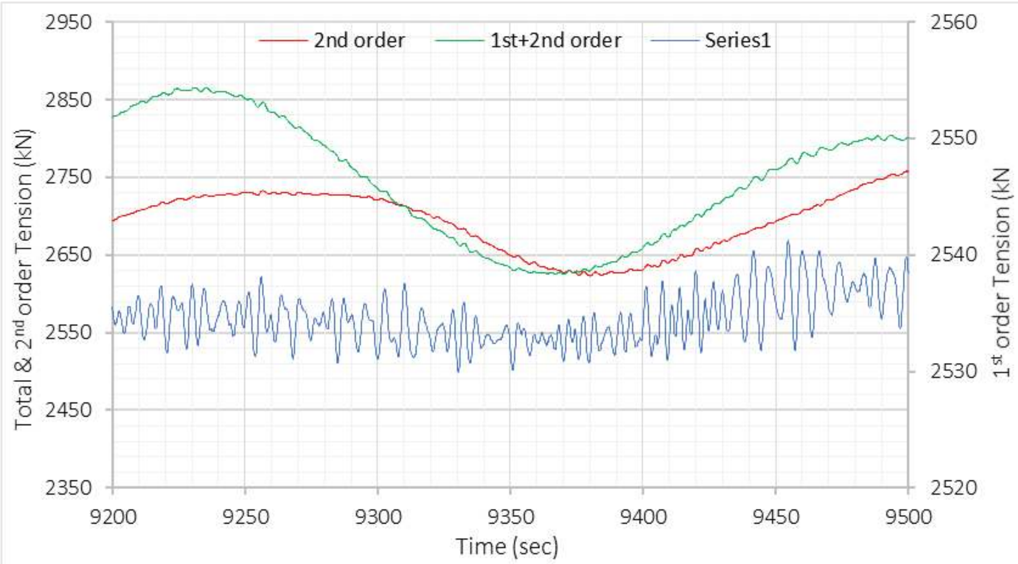

Figure 4-18 Time series of tension in Line 5 - arc length 826m at 9200-9500sec. Load case 77 with Hs=1.725m; Tp=6.35m; V_w=14.85m/s; V_c=0.68m/s; μ=180° collinear

Figure 4-19 Surge response for load case 77 with Hs=1.725m; Tp=6.35m; Vw=14.85m/s; Vc=0.68m/s; μ=180° collinear

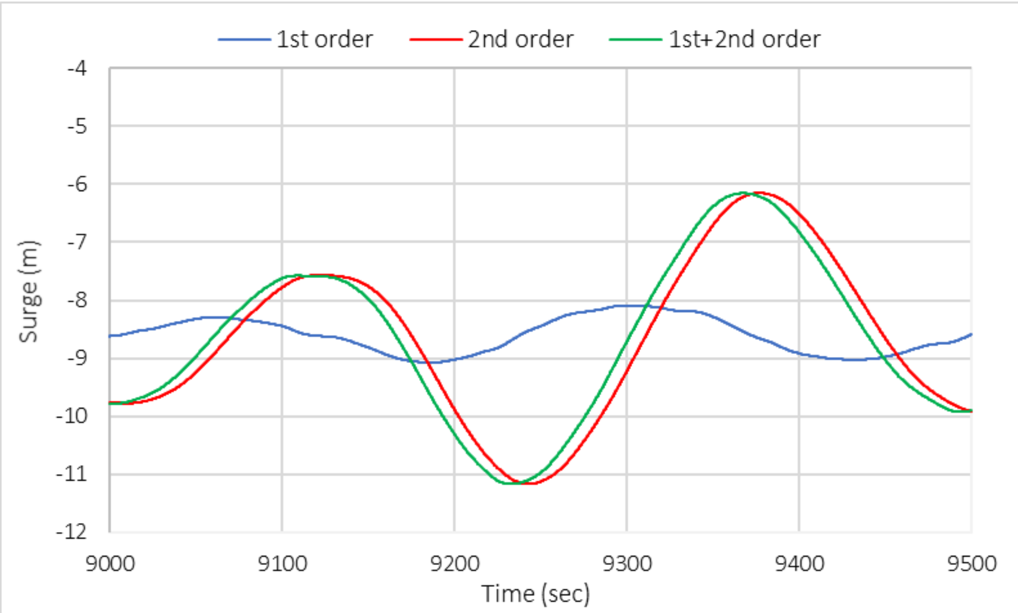

Figure 4-20 Surge response for load case 77 at 9000-9500sec with Hs=1.725m; Tp=6.35m; Vw=14.85m/s; Vc=0.68m/s; μ=180^o collinear

Surge vessel response generated by 1st order wave load, 2nd order wave load and combination of both presented in Figure 4-19. As can be seen in this figure, surge response of 1st order wave load relatively small compare to 2nd order load. Surge response of 1st order wave load has double amplitude approx. of 1.5m, while 2nd order wave load has double amplitude approx. of 7m.

As previously discussed in Section 4.2.3, in the horizontal motion (surge, sway, yaw), 2nd order wave load component has significant effect on vessel offset and line tension of moored vessel compared to 1st order wave load component. However, in term of fatigue life, 1st order wave load induces higher fatigue damage (shorter fatigue life) on the mooring line compare to 2nd order component. The time series of tension in mooring line 5 at arc length 826m is shown in Figure 4-17. The highest line tension of 1st order component, 2690kN, is less than those of 2nd order component with 2843.7kN. However, the number of cycles in 1st order component is more than 2nd order component, where 1st order component has 3166 cycles while 2nd order component has 3118 cycles. The higher number of cycles leads to higher fatigue damage (shorter fatigue life).

5. CONCLUSION

5.1 Conclusion from results and discussion

This thesis investigates several parameters which could affect the fatigue life of mooring lines by setting up a series of case study for a FLNG with external turret mooring system. Coupled dynamic analysis under different condition were performed to investigate the effects of mooring pretension, water depth and wave load type on the fatigue life of mooring lines.

Based on the numerical results and discussions, following conclusion can be made as follows:

1. Mooring system with smaller pretension has lower dynamic line tension. However, the smaller pretension lead to larger vessel offset and smaller mooring stiffness. This will increase the tension range and standard deviation (STD) that lead to higher fatigue damage (shorter fatigue life).
2. In the deeper water depth, the weight of mooring line will increase due to increases in mooring line length that will be followed by increases in pretension. The increase in mooring length will also give additional drag force on the line. This increase will lead to increase of effective and mean tension. In term of fatigue life, the higher water depth will reduce the fatigue life in mooring system.
3. The contribution of 2nd order wave component on vessel offset and line tension of moored vessel is more significant compare to 1st order wave component. However, in term of fatigue life, 1st order wave load induces higher fatigue damage (shorter fatigue life) compare to 2nd order component.

Mooring pretension, water depth, and wave load component, all these parameters affect the fatigue life of mooring line. Analysis results obtained from these parametric studies can be used as guidance to mooring designer for designing fatigue life of mooring lines on floating structures.

5.2 Recommendation

Some recommendation for future work related to this thesis are identified as follows:

1. Pretension mooring case studied in this thesis are compared in 3 different cases, where the gap difference of pretension value between each case study is quite significant (approx. 780kN). It is recommended to add more cases where the gap difference of pretension is closer each other, thus the trend of fatigue life results with more details can be assessed.
2. In this thesis, fatigue damages are calculated using Rainflow method. It would be interesting to perform a comparison study between fatigue damage methods as per stated in code/standards, e.g.: Rainflow counting compare with Combined spectrum approach.
3. In order to study the effect of each parameter optimally, it is recommended using combinatorial factor design.

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APPENDIX A

MOSES Input Model

Input MOSES: Model FLNG

```
$
&model_def -save
&model_def -flood no
&dimen -save -dimen meters m-tons
$
&set vessel  = flng
&set vName   = flng
&set vdepth  = 38.0   $ barge depth
&set vbeam   = 64.0   $ barge beam
&set vlength = 381.4  $ barge length (LBP)
&set l_draft = 11.0
&set h_draft = 15.5
&set diftype = 3ddif
$
&desc body flng
$
$*****************************************
$ MAIN HULL
$*****************************************
$
$TURRET SUPPORT
pgen -perm 1.00 -loc 0.0 0.0 0.0 -diftyp %diftype -cs_wind 1 1 0 -cs_cur 1 1 1
PLANE  -52.090        -CARTES 0.000,38.200  12.000,38.200  12.000,45.200
PLANE  -24.774        -CARTES 0.000,38.200  12.000,38.200  12.000,45.200
PLANE  -15.770        -CARTES 0.000,31.817  12.000,31.817  12.000,45.200
PLANE  -15.770        -CARTES 0.000,38.000  12.000,38.000  12.000,45.200
PLANE   0             -CARTES 0.000,20.775  12.000,38.000
end_pgen
$
pgen -perm 1.000625 -loc 0.0 0.0 -0.02 -diftyp %diftype -cs_wind 1 1 0 -cs_cur 1 1 1
$--FRONT---
PLANE  -15.770        -CARTES 0.000,31.817   24.756,31.817  24.756,32.000  24.756,36.000
       24.756,38.000  00.000,38.000  $ 21ST
PLANE  -9.535         -CARTES 0.000,27.536   24.756,27.536  27.513,31.817  27.513,32.000
       27.513,36.000  27.513,38.000  00.000,38.000  $ 20.5ST
PLANE  -4.768         -CARTES 0.000,24.000   24.756,24.000  28.000,28.986  29.802,31.817
       29.802,32.000  29.802,36.000  29.802,38.000  00.000,38.000  $32.000,38.000 $ 20ST
$--HULL---
PLANE  0              -CARTES 0.000,12.000   19.000,12.000  20.000,13.599  24.000,19.708
       24.756,20.775  28.000,25.817  32.000,31.926  32.000,32.000  32.000,36.000
       32.000,38.000  00.000,38.000  $32.000,36.000 32.000,38.000  $ 20ST / FP
PLANE  4.7675         -CARTES 0.000,8.480    19.000,8.480   20.000,9.211
       23.440,11.772  24.000,12.524  28.000,18.553  32.000,24.543  32.000,28.000
       32.000,32.000  32.000,36.000  32.000,38.000  00.000,38.000  $ 19.75ST
PLANE  9.535          -CARTES 0.000,4.888    19.000,4.888   20.000,5.637   24.000,8.630
       28.000,11.623  28.506,12.071  32.000,17.359  32.000,24.000  32.000,28.000
       32.000,32.000  32.000,36.000  32.000,38.000  00.000,38.000  $ 19.50ST
PLANE  14.302         -CARTES 0.000,1.396    19.000,1.396   20.000,2.140   24.000,5.118
       28.000,8.096   32.000,11.074  32.000,16.000  32.000,20.000  32.000,24.000
       32.000,28.000  32.000,32.000  32.000,36.000  32.000,38.000  00.000,38.000  $ 19.25ST
PLANE  16.130         -CARTES 0.000,0.000    19.000,0.000   20.000,0.772   24.000,3.752
       24.247,4.000   28.000,6.801   29.633,8.000   32.000,9.752   32.000,12.000
       32.000,16.000  32.000,24.000  32.000,28.000  32.000,32.000  32.000,36.000
       32.000,38.000  00.000,38.000
PLANE  17.130         -CARTES 0.000,0.000    20.000,0.000   24.000,3.011   25.212,4.000
       28.000,6.064   30.636,8.000   32.000,9.003   32.000,12.000  32.000,16.000
       32.000,24.000  32.000,28.000  32.000,32.000  32.000,36.000  32.000,38.000
       00.000,38.000  $ STATION BANTU(19+1)
PLANE  1*19.070       -CARTES 0.000,0.000    21.852,0.000   24.000,1.555   27.202,4.000
       28.000,4.519   32.000,7.483   32.000,8.000   32.000,20.000  32.000,24.000
       32.000,28.000  32.000,32.000  32.000,36.000  32.000,38.000  00.000,38.000  $ 19ST
PLANE  21.156         -CARTES 0.000,0.000    24.000,0.000   28.000,2.987   29.258,4.000
       32.000,5.946   32.000,8.000   32.000,12.000  32.000,20.000  32.000,24.000
       32.000,28.000  32.000,32.000  32.000,38.000  00.000,38.000  $ ST AUX(19-1)
PLANE  25.130         -CARTES 0.000,0.000    28.000,0.000   32.000,3.018   32.000,4.000
       32.000,8.000   32.000,12.000  32.000,20.000  32.000,24.000  32.000,28.000
       32.000,32.000  32.000,36.000  32.000,38.000  00.000,38.000  $ ST AUX(19-1)
PLANE  2*19.070       -CARTES 0.000,0.000    29.500,0.000 \
                      -CIRC   29.500,2.5,2.5,10,10,10 \
                      -CARTES 32.000,4.000   32.000,8.000   32.000,12.000  32.000,16.000
       32.000,20.000  32.000,24.000  32.000,28.000  32.000,32.000  32.000,36.000
       32.000,38.000  00.000,38.000  $ 18ST
PLANE  3*19.070 4*19.070 5*19.070 6*19.070 7*19.070 8*19.070 9*19.070 10*19.070 11*19.070
       12*19.070 13*19.070 14*19.070 15*19.070 16*19.070 17*19.070 18*19.070 \
```

```
                    -CARTES 0.000,0.000    29.500,0.000 \
                    -CIRC   29.500,2.5,2.5,10,10,10 \
                    -CARTES 32.000,4.000   32.000,8.000   32.000,12.000  32.000,16.000
      32.000,20.000  32.000,24.000  32.000,28.000  32.000,32.000  32.000,36.000
      32.000,38.000  00.000,38.000
PLANE  19*19.070-7.970 -CARTES       0.000,0.000    29.500,0.000 \
                    -CIRC   29.500,2.5,2.5,10,10,10 \
                    -CARTES 32.000,2.500   32.000,4.000   32.000,8.000   32.000,12.000
      32.000,16.000  32.000,20.000  32.000,24.000  32.000,28.000  32.000,32.000
      32.000,36.000  32.000,38.000  0.000,38.000   $ 1ST-7.970metre
PLANE  19*19.070       -CARTES 0.000,0.000    7.290,0.000    7.290,3.292    29.500,3.292 \
                    -CIRC   29.500,5.792,2.5,10,10,10 \
                    -CARTES 32.000,5.792   32.000,8.000   32.000,12.000  32.000,16.000
      32.000,20.000  32.000,24.000  32.000,28.000  32.000,32.000  32.000,36.000
      32.000,38.000  0.000,38.000   $ 1ST
PLANE  19*19.070+4.768 -CARTES 0.000,0.000    7.290,0.000    7.290,5.187    29.500,5.187 \
                    -CIRC   29.500,7.687,2.5,10,10,10 \
                    -CARTES 32.000,7.687   32.000,8.000   32.000,12.000  32.000,16.000
      32.000,20.000  32.000,24.000  32.000,28.000  32.000,32.000  32.000,36.000
      32.000,38.000  0.000,38.000   $ 0.75ST
PLANE  19*19.070+9.535 -CARTES 0.000,0.000    7.290,0.000    7.290,7.183    29.500,7.183 \
                    -CIRC   29.500,9.683,2.5,10,10,10 \
                    -CARTES 32.000,9.683   32.000,12.000  32.000,16.000  32.000,20.000
      32.000,24.000  32.000,28.000  32.000,32.000  32.000,36.000  32.000,38.000
      0.000,38.000   $ 0.5ST
PLANE  19*19.070+14.303 -CARTES 0.000,0.000  7.290,0.000    7.290,9.078    29.500,9.078 \
                    -CIRC   29.500,11.578,2.5,10,10,10 \
                    -CARTES 32.000,11.578  32.000,12.000  32.000,16.000  32.000,20.000
      32.000,24.000  32.000,28.000  32.000,32.000  32.000,36.000  32.000,38.000
      0.000,38.000   $ 0.25ST
PLANE  20*19.070       -CARTES 0.000,0.000    7.290,0.000    7.290,10.974   29.500,10.974 \
                    -CIRC   29.500,13.474,2.5,10,10,10 \
                    -CARTES 32.000,13.474  32.000,16.000  32.000,20.000  32.000,24.000
      32.000,28.000  32.000,32.000  32.000,36.000  32.000,38.000  0.000,38.000   $ 0ST
end_pgen
```

Input MOSES: Hydrodynamic Analysis

```
$*******************************************************************
Set devices
&device -pri device -oec n
&style output -lpi 10
&dime -dim meters m-tons
$%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
$************************  SET FLAGS  ******************************
$%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
$
&Title - Motion Analysis
$
inmodel
&instate -condition %vessel %h_draft 0 0
&weight -compute %vessel 24.36 21.49 124.61 125.50
$*********************************************************************
Hydrostatic
hstat
 cform 1.0 0 0 -draft .5 50
 rep
 end
end
&equi
&stat b_w -h
$********************************************************************
Plot Model
&pltm
&subt MOSES Model Plot (Isometric View)
pic iso
&subt MOSES Model Plot (Starboard View)
pic sta
&subt MOSES Model Plot (Top View)
pic top
&subt MOSES Model Plot (Bow View)
pic bow
end
&para -m_dist 10
hydro
  g_p %vessel% -heading 0 22.5 45 67.5 90 112.5 135 157.5 180 202.5 225 247.5 270 292.5
315 337.5
  V_MATRICES
  end
  e_total
        v_mdrift
               vlist
               report
               plot 2  3  4  5  6  7  8 -no_edit
               plot 2  9 10 11 12 13 14 -no_edit
               plot 2 15 16 17 18 19 20 -no_edit
               plot 2 21 22 23 24 25 26 -no_edit
               plot 2 27 28 29 30 31 32 -no_edit
               plot 2 33 34 35 36 37 38 -no_edit
               plot 2 39 40 41 42 43 44 -no_edit
               plot 2 45 46 47 48 49 50 -no_edit
               plot 2 51 52 53 54 55 56 -no_edit
        end
end
freq_r
  rao -PERIOD  3      4      4.5    5      5.5    6      6.5    7      7.5    8   \
               8.5    9      9.5    10     10.5   11     11.5   12     12.5   13  \
               13.5   14     14.5   15     15.5   16     16.5   17     17.5   18  \
               18.5   19     19.5   20     20.5   21     21.5   22     22.5   23  \
               23.5   24     24.5   25
  fp_std &body(cg %vessel)
  fr_point &body(cg %vessel)
  vlist
  $plot 2 3 15 27 39 51 63 75 87 99 -no_edit $surge
  $plot 2 3+(1*2) 15+(1*2) 27+(1*2) 39+(1*2) 51+(1*2) 63+(1*2) 75+(1*2) 87+(1*2) 99+(1*2) -
no_edit $sway
  $plot 2 3+(2*2) 15+(2*2) 27+(2*2) 39+(2*2) 51+(2*2) 63+(2*2) 75+(2*2) 87+(2*2) 99+(2*2) -
no_edit $heave
  $plot 2 3+(3*2) 15+(3*2) 27+(3*2) 39+(3*2) 51+(3*2) 63+(3*2) 75+(3*2) 87+(3*2) 99+(3*2) -
no_edit $roll
```

```
  $plot 2 3+(4*2) 15+(4*2) 27+(4*2) 39+(4*2) 51+(4*2) 63+(4*2) 75+(4*2) 87+(4*2) 99+(4*2) -
no_edit $pitch
  $plot 2 3+(5*2) 15+(5*2) 27+(5*2) 39+(5*2) 51+(5*2) 63+(5*2) 75+(5*2) 87+(5*2) 99+(5*2) -
no_edit $yaw
  $end
       EQU_SUM
  matrices -file
  end
  exforce -file
  end
end
&finish
```

APPENDIX B

Hydrodynamic Output

Added Mass & Damping Matrix

```
$ MATRICES
$ Dimensions are Meters   and M-Tons
Frequency     0.2513          Period       25.0000
Added Mass
  3.48724E-02 -4.13437E-03  3.70014E-02 -1.44354E-01  2.73569E+01  2.06987E+00
  1.01227E-02  8.34779E-01 -1.55124E-02  5.41115E+00  6.57567E-01  2.76388E+00
 -1.19014E-02 -4.13757E-03  2.73604E+00  1.02429E-01 -2.24289E+00 -3.01195E+00
 -1.44354E-01  5.41115E+00  1.02429E-01  2.83152E+02 -1.70434E+02  4.92151E+01
  2.73569E+01  6.57567E-01 -2.24289E+00  5.65224E+01  3.01130E+04 -9.75587E+02
  2.06987E+00  2.76388E+00 -3.01195E+00 -2.15764E+02  1.90427E+03  7.11682E+03
Damping
  5.09544E-03 -2.24181E-04  1.76002E-02 -3.94614E-03  1.91633E+00  9.89303E-02
  5.85666E-04  3.19471E-02 -6.87698E-03  4.12733E-01  1.18221E-02 -2.92984E+00
  4.19212E-04 -7.25086E-05  4.96985E-01  4.26496E-02  5.53387E+00 -1.27614E+00
 -3.94614E-03  4.12733E-01  4.26496E-02  2.16285E+01 -4.43812E+01 -7.18926E+01
  1.91633E+00  1.18221E-02  5.53387E+00  4.05390E+01  4.36896E+03 -5.01105E+02
  9.89303E-02 -2.92984E+00 -1.27614E+00 -7.68158E+01  4.01007E+02  1.43503E+03
Frequency     0.2565          Period       24.5000
Added Mass
  3.47691E-02 -4.11737E-03  3.50622E-02 -1.43490E-01  2.70345E+01  2.05594E+00
  1.00348E-02  8.41808E-01 -1.46961E-02  5.45804E+00  6.60155E-01  2.78087E+00
 -1.18223E-02 -4.12716E-03  2.68202E+00  9.81088E-02 -2.17742E+00 -2.86777E+00
 -1.43490E-01  5.45804E+00  9.81088E-02  2.83517E+02 -1.64159E+02  4.92802E+01
  2.70345E+01  6.60155E-01 -2.17742E+00  5.18925E+01  2.98908E+04 -9.15598E+02
  2.05594E+00  2.78087E+00 -2.86777E+00 -2.16721E+02  1.84699E+03  7.20721E+03
Damping
  5.19913E-03 -2.55535E-04  1.74790E-02 -4.19962E-03  2.10680E+00  1.08492E-01
  6.45629E-04  3.61097E-02 -6.85531E-03  4.27516E-01  1.42699E-02 -2.93388E+00
  3.29541E-04 -9.87699E-05  5.03140E-01  4.20420E-02  5.50462E+00 -1.27271E+00
 -4.19962E-03  4.27516E-01  4.20420E-02  2.17908E+01 -4.53061E+01 -7.21580E+01
  2.10680E+00  1.42699E-02  5.50462E+00  4.02794E+01  4.49911E+03 -4.99060E+02
  1.08492E-01 -2.93388E+00 -1.27271E+00 -7.82120E+01  4.13891E+02  1.44854E+03
Frequency     0.2618          Period       24.0000
Added Mass
  3.46615E-02 -4.09966E-03  3.30423E-02 -1.42590E-01  2.66986E+01  2.04143E+00
  9.94331E-03  8.49130E-01 -1.38457E-02  5.50687E+00  6.62850E-01  2.79855E+00
 -1.17400E-02 -4.11633E-03  2.62576E+00  9.36082E-02 -2.10928E+00 -2.71758E+00
 -1.42590E-01  5.50687E+00  9.36082E-02  2.83896E+02 -1.57623E+02  4.93478E+01
  2.66986E+01  6.62850E-01 -2.10928E+00  4.70698E+01  2.96592E+04 -8.53109E+02
  2.04143E+00  2.79855E+00 -2.71758E+00 -2.17718E+02  1.78731E+03  7.30137E+03
Damping
  5.31982E-03 -2.88195E-04  1.73526E-02 -4.46366E-03  2.30490E+00  1.18452E-01
  7.08090E-04  4.04879E-02 -6.83273E-03  4.43941E-01  1.68198E-02 -2.94614E+00
  2.36134E-04 -1.26125E-04  5.09750E-01  4.14099E-02  5.51212E+00 -1.26914E+00
 -4.46366E-03  4.43941E-01  4.14099E-02  2.20494E+01 -4.62695E+01 -7.26306E+01
  2.30490E+00  1.68198E-02  5.51212E+00  4.00090E+01  4.65305E+03 -4.96929E+02
  1.18452E-01 -2.94614E+00 -1.26914E+00 -7.98626E+01  4.27311E+02  1.46713E+03
Frequency     0.2674          Period       23.5000
Added Mass
  3.45494E-02 -4.08120E-03  3.09364E-02 -1.41652E-01  2.63483E+01  2.02629E+00
  9.84790E-03  8.56764E-01 -1.29592E-02  5.55778E+00  6.65661E-01  2.81700E+00
 -1.16542E-02 -4.10503E-03  2.56710E+00  8.89162E-02 -2.03812E+00 -2.56100E+00
 -1.41652E-01  5.55778E+00  8.89162E-02  2.84292E+02 -1.50808E+02  4.94185E+01
  2.63483E+01  6.65661E-01 -2.03812E+00  4.20419E+01  2.94179E+04 -7.87961E+02
  2.02629E+00  2.81700E+00 -2.56100E+00 -2.18758E+02  1.72510E+03  7.39953E+03
Damping
  5.45710E-03 -3.22244E-04  1.72209E-02 -4.73894E-03  2.51115E+00  1.28835E-01
  7.73209E-04  4.50620E-02 -6.80919E-03  4.61299E-01  1.94781E-02 -2.96075E+00
  1.38752E-04 -1.54645E-04  5.16743E-01  4.07512E-02  5.53940E+00 -1.26542E+00
 -4.73894E-03  4.61299E-01  4.07512E-02  2.23659E+01 -4.72737E+01 -7.31681E+01
  2.51115E+00  1.94781E-02  5.53940E+00  3.97273E+01  4.82410E+03 -4.94708E+02
  1.28835E-01 -2.96075E+00 -1.26542E+00 -8.16282E+01  4.41302E+02  1.48822E+03
Frequency     0.2732          Period       23.0000
Added Mass
  3.44323E-02 -4.06194E-03  2.87390E-02 -1.40673E-01  2.59829E+01  2.01050E+00
  9.74833E-03  8.64729E-01 -1.20341E-02  5.61091E+00  6.68594E-01  2.83625E+00
 -1.15646E-02 -4.09323E-03  2.50589E+00  8.40201E-02 -1.96391E+00 -2.39760E+00
 -1.40673E-01  5.61091E+00  8.40201E-02  2.84705E+02 -1.43698E+02  4.94918E+01
  2.59829E+01  6.68594E-01 -1.96391E+00  3.67953E+01  2.91660E+04 -7.19980E+02
  2.01050E+00  2.83625E+00 -2.39760E+00 -2.19843E+02  1.66019E+03  7.50196E+03
Damping
  5.61169E-03 -3.57774E-04  1.70834E-02 -5.02618E-03  2.72608E+00  1.39670E-01
  8.41159E-04  4.98249E-02 -6.78462E-03  4.79164E-01  2.22520E-02 -2.97406E+00
  3.71366E-05 -1.84405E-04  5.24084E-01  4.00641E-02  5.57618E+00 -1.26154E+00
 -5.02618E-03  4.79164E-01  4.00641E-02  2.27264E+01 -4.83215E+01 -7.36816E+01
  2.72608E+00  2.22520E-02  5.57618E+00  3.94333E+01  5.00870E+03 -4.92390E+02
  1.39670E-01 -2.97406E+00 -1.26154E+00 -8.34232E+01  4.55901E+02  1.51033E+03
Frequency     0.2793          Period       22.5000
Added Mass
  3.43101E-02 -4.04182E-03  2.64439E-02 -1.39651E-01  2.56012E+01  1.99401E+00
  9.64435E-03  8.73049E-01 -1.10679E-02  5.66639E+00  6.71657E-01  2.85634E+00
 -1.14711E-02 -4.08092E-03  2.44197E+00  7.89065E-02 -1.88641E+00 -2.22695E+00
 -1.39651E-01  5.66639E+00  7.89065E-02  2.85136E+02 -1.36271E+02  4.95689E+01
  2.56012E+01  6.71657E-01 -1.88641E+00  3.13156E+01  2.89030E+04 -6.48978E+02
  1.99401E+00  2.85634E+00 -2.22695E+00 -2.20976E+02  1.59239E+03  7.60895E+03
Damping
  5.78605E-03 -3.94883E-04  1.69399E-02 -5.32619E-03  2.95026E+00  1.50987E-01
  9.12129E-04  5.47825E-02 -6.75897E-03  4.97414E-01  2.51492E-02 -2.98475E+00
 -6.89953E-05 -2.15487E-04  5.31769E-01  3.93466E-02  5.61818E+00 -1.25749E+00
 -5.32619E-03  4.97414E-01  3.93466E-02  2.31519E+01 -4.94160E+01 -7.41396E+01
  2.95026E+00  2.51492E-02  5.61818E+00  3.91263E+01  5.20621E+03 -4.89969E+02
  1.50987E-01 -2.98475E+00 -1.25749E+00 -8.52196E+01  4.71150E+02  1.53315E+03
```

```
Frequency     0.2856          Period       22.0000
Added Mass
  3.41823E-02 -4.02078E-03  2.40444E-02 -1.38582E-01  2.52022E+01  1.97677E+00
  9.53564E-03  8.81747E-01 -1.00578E-02  5.72440E+00  6.74859E-01  2.87735E+00
 -1.13733E-02 -4.06804E-03  2.37513E+00  7.35604E-02 -1.80546E+00 -2.04854E+00
 -1.38582E-01  5.72440E+00  7.35604E-02  2.85587E+02 -1.28507E+02  4.96492E+01
  2.52022E+01  6.74859E-01 -1.80546E+00  2.55868E+01  2.86279E+04 -5.74748E+02
  1.97677E+00  2.87735E+00 -2.04854E+00 -2.22160E+02  1.52150E+03  7.72080E+03
Damping
  6.18897E-03 -4.33679E-04  1.67898E-02 -5.63984E-03  3.17925E+00  1.62817E-01
  9.86325E-04  5.99372E-02 -6.73214E-03  5.15801E-01  2.81781E-02 -2.99048E+00
 -1.79952E-04 -2.47982E-04  5.39772E-01  3.85962E-02  5.65592E+00 -1.25325E+00
 -5.63984E-03  5.15801E-01  3.85962E-02  2.37229E+01 -5.05602E+01 -7.44860E+01
  3.17925E+00  2.81781E-02  5.65592E+00  3.88053E+01  5.43869E+03 -4.87439E+02
  1.62817E-01 -2.99048E+00 -1.25325E+00 -8.69653E+01  4.87091E+02  1.56836E+03
Frequency     0.2922          Period       21.5000
Added Mass
  3.40485E-02 -3.99876E-03  2.15334E-02 -1.37463E-01  2.47846E+01  1.95873E+00
  9.42187E-03  8.90849E-01 -9.00067E-03  5.78511E+00  6.78210E-01  2.89935E+00
 -1.12709E-02 -4.05457E-03  2.30519E+00  6.79656E-02 -1.72066E+00 -1.86184E+00
 -1.37463E-01  5.78511E+00  6.79656E-02  2.86059E+02 -1.20382E+02  4.97333E+01
  2.47846E+01  6.78210E-01 -1.72066E+00  1.95915E+01  2.83401E+04 -4.97067E+02
  1.95873E+00  2.89935E+00 -1.86184E+00 -2.23400E+02  1.44732E+03  7.83784E+03
Damping
  6.43906E-03 -4.74279E-04  1.66327E-02 -5.96808E-03  3.42308E+00  1.75198E-01
  1.06397E-03  6.54628E-02 -6.70407E-03  5.38239E-01  3.13479E-02 -3.02159E+00
 -2.96068E-04 -2.81988E-04  5.48468E-01  3.78123E-02  5.75680E+00 -1.24882E+00
 -5.96808E-03  5.38239E-01  3.78123E-02  2.46289E+01 -5.17573E+01 -7.54600E+01
  3.42308E+00  3.13479E-02  5.75680E+00  3.84697E+01  5.69371E+03 -4.84790E+02
  1.75198E-01 -3.02159E+00 -1.24882E+00 -8.94037E+01  5.03774E+02  1.60859E+03
Frequency     0.2992          Period       21.0000
Added Mass
  3.39084E-02 -3.97570E-03  1.89028E-02 -1.36291E-01  2.43472E+01  1.93983E+00
  9.30268E-03  9.00385E-01 -7.89323E-03  5.84871E+00  6.81721E-01  2.92238E+00
 -1.11637E-02 -4.04045E-03  2.23191E+00  6.21044E-02 -1.63190E+00 -1.66624E+00
 -1.36291E-01  5.84871E+00  6.21044E-02  2.86554E+02 -1.11869E+02  4.98209E+01
  2.43472E+01  6.81721E-01 -1.63190E+00  1.33108E+01  2.80386E+04 -4.15685E+02
  1.93983E+00  2.92238E+00 -1.66624E+00 -2.24699E+02  1.36961E+03  7.96048E+03
Damping
  6.83691E-03 -5.16813E-04  1.64681E-02 -6.31194E-03  3.67520E+00  1.88168E-01
  1.14532E-03  7.12034E-02 -6.67467E-03  5.60576E-01  3.46686E-02 -3.04498E+00
 -4.17715E-04 -3.17614E-04  5.57573E-01  3.69910E-02  5.86153E+00 -1.24417E+00
 -6.31194E-03  5.60576E-01  3.69910E-02  2.52199E+01 -5.30115E+01 -7.62565E+01
  3.67520E+00  3.46686E-02  5.86153E+00  3.81180E+01  5.99192E+03 -4.82015E+02
  1.88168E-01 -3.04498E+00 -1.24417E+00 -9.17343E+01  5.21252E+02  1.66258E+03
Frequency     0.3065          Period       20.5000
Added Mass
  3.37615E-02 -3.95151E-03  1.61439E-02 -1.35062E-01  2.38884E+01  1.92001E+00
  9.17768E-03  9.10386E-01 -6.73177E-03  5.91541E+00  6.85403E-01  2.94654E+00
 -1.10513E-02 -4.02565E-03  2.15507E+00  5.59574E-02 -1.53873E+00 -1.46110E+00
 -1.35062E-01  5.91541E+00  5.59574E-02  2.87072E+02 -1.02942E+02  4.99134E+01
  2.38884E+01  6.85403E-01 -1.53873E+00  6.72363E+00  2.77224E+04 -3.30334E+02
  1.92001E+00  2.94654E+00 -1.46110E+00 -2.26061E+02  1.28811E+03  8.08908E+03
Damping
  7.22751E-03 -5.61421E-04  1.62956E-02 -6.67259E-03  3.94027E+00  2.01771E-01
  1.23063E-03  7.71914E-02 -6.64383E-03  5.83204E-01  3.81513E-02 -3.06325E+00
 -5.45295E-04 -3.54978E-04  5.67165E-01  3.61298E-02  5.97952E+00 -1.23930E+00
 -6.67259E-03  5.83204E-01  3.61298E-02  2.54214E+01 -5.43268E+01 -7.69392E+01
  3.94027E+00  3.81513E-02  5.97952E+00  3.77492E+01  6.31680E+03 -4.79105E+02
  2.01771E-01 -3.06325E+00 -1.23930E+00 -9.40260E+01  5.39582E+02  1.71830E+03
Frequency     0.3142          Period       20.0000
Added Mass
  3.36072E-02 -3.92612E-03  1.32470E-02 -1.33772E-01  2.34066E+01  1.89919E+00
  9.04643E-03  9.20887E-01 -5.51223E-03  5.98544E+00  6.89269E-01  2.97192E+00
 -1.09332E-02 -4.01011E-03  2.07438E+00  4.95029E-02 -1.44092E+00 -1.24571E+00
 -1.33772E-01  5.98544E+00  4.95029E-02  2.87616E+02 -9.35679E+01  5.00109E+01
  2.34066E+01  6.89269E-01 -1.44092E+00 -1.92864E-01  2.73904E+04 -2.40716E+02
  1.89919E+00  2.97192E+00 -1.24571E+00 -2.27491E+02  1.20253E+03  8.22411E+03
Damping
  7.62713E-03 -6.08260E-04  1.61144E-02 -7.05126E-03  4.21885E+00  2.16054E-01
  1.32021E-03  8.35769E-02 -6.61144E-03  6.09355E-01  4.18082E-02 -3.10121E+00
 -6.79254E-04 -3.94209E-04  5.77481E-01  3.52265E-02  6.15033E+00 -1.23418E+00
 -7.05126E-03  6.09355E-01  3.52265E-02  2.59058E+01 -5.57077E+01 -7.81135E+01
  4.21885E+00  4.18082E-02  6.15033E+00  3.73622E+01  6.69143E+03 -4.76049E+02
  2.16054E-01 -3.10121E+00 -1.23418E+00 -9.68897E+01  5.58828E+02  1.78992E+03
Frequency     0.3222          Period       19.5000
Added Mass
  3.32701E-02 -3.82777E-03  1.22979E-02 -1.32187E-01  2.25695E+01  1.86320E+00
  8.80526E-03  9.25236E-01 -4.99197E-03  6.05306E+00  6.86370E-01  2.96335E+00
 -1.04806E-02 -3.89236E-03  2.00665E+00  4.84365E-02 -1.37705E+00 -1.15082E+00
 -1.32187E-01  6.05306E+00  4.84365E-02  2.88040E+02 -8.56704E+01  4.95507E+01
  2.25695E+01  6.86370E-01 -1.37705E+00 -2.43761E+00  2.67689E+04 -2.02587E+02
  1.86320E+00  2.96335E+00 -1.15082E+00 -2.27142E+02  1.11644E+03  8.40614E+03
Damping
  7.82445E-03 -6.61730E-04  1.55252E-02 -7.24171E-03  4.47179E+00  2.28779E-01
  1.39721E-03  9.44338E-02 -6.39622E-03  6.54594E-01  4.83942E-02 -3.11350E+00
 -7.72479E-04 -4.35299E-04  5.78471E-01  3.34604E-02  6.23700E+00 -1.19864E+00
 -7.24171E-03  6.54594E-01  3.34604E-02  2.64260E+01 -5.57724E+01 -7.89249E+01
  4.47179E+00  4.83942E-02  6.23700E+00  3.59464E+01  6.94921E+03 -4.59219E+02
  2.28779E-01 -3.11350E+00 -1.19864E+00 -1.00299E+02  5.67663E+02  1.86045E+03
Frequency     0.3307          Period       19.0000
Added Mass
  3.29153E-02 -3.72424E-03  1.12989E-02 -1.30519E-01  2.16884E+01  1.82531E+00
  8.55139E-03  9.29814E-01 -4.44433E-03  6.12424E+00  6.83318E-01  2.95432E+00
 -1.00042E-02 -3.76842E-03  1.93535E+00  4.73140E-02 -1.30992E+00 -1.05094E+00
 -1.30519E-01  6.12424E+00  4.73140E-02  2.88486E+02 -7.73573E+01  4.90658E+01
  2.16884E+01  6.83318E-01 -1.30992E+00 -4.80050E+00  2.61148E+04 -1.62451E+02
  1.82531E+00  2.95432E+00 -1.05094E+00 -2.26776E+02  1.02581E+03  8.59776E+03
Damping
  8.08384E-03 -7.18013E-04  1.49050E-02 -7.44219E-03  4.73679E+00  2.42175E-01
  1.47827E-03  1.05886E-01 -6.16967E-03  7.02801E-01  5.53268E-02 -3.13105E+00
 -8.70610E-04 -4.78552E-04  5.79682E-01  3.16021E-02  6.36065E+00 -1.16124E+00
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 -7.44219E-03  7.02801E-01  3.16021E-02  2.71623E+01 -5.58403E+01 -7.98915E+01
  4.73679E+00  5.53268E-02  6.36065E+00  3.44563E+01  7.24782E+03 -4.41502E+02
  2.42175E-01 -3.13105E+00 -1.16124E+00 -1.04000E+02  5.76963E+02  1.94287E+03
Frequency     0.3396          Period       18.5000
Added Mass
  3.25421E-02 -3.59505E-03  1.12270E-02 -1.28970E-01  2.06950E+01  1.78516E+00
  8.27997E-03  9.28880E-01 -4.26125E-03  6.18319E+00  6.74272E-01  2.92219E+00
 -9.49628E-03 -3.61496E-03  1.87257E+00  4.84413E-02 -1.28192E+00 -1.01336E+00
 -1.28970E-01  6.18319E+00  4.84413E-02  2.88798E+02 -7.04734E+01  4.83858E+01
  2.06950E+01  6.74272E-01 -1.28192E+00 -4.91112E+00  2.53541E+04 -1.49645E+02
  1.78516E+00  2.92219E+00 -1.01336E+00 -2.25106E+02  9.41358E+02  8.79738E+03
Damping
  8.23193E-03 -7.70680E-04  1.42811E-02 -7.52845E-03  4.95769E+00  2.53614E-01
  1.54270E-03  1.19730E-01 -5.92665E-03  7.63712E-01  6.31832E-02 -3.13249E+00
 -9.08854E-04 -5.07965E-04  5.76568E-01  2.98712E-02  6.43704E+00 -1.12094E+00
 -7.52845E-03  7.63712E-01  2.98712E-02  2.78751E+01 -5.54425E+01 -8.06233E+01
  4.95769E+00  6.31832E-02  6.43704E+00  3.29709E+01  7.48782E+03 -4.22241E+02
  2.53614E-01 -3.13249E+00 -1.12094E+00 -1.07811E+02  5.81513E+02  2.04652E+03
Frequency     0.3491          Period       18.0000
Added Mass
  3.21482E-02 -3.45868E-03  1.11512E-02 -1.27336E-01  1.96465E+01  1.74278E+00
  7.99347E-03  9.27894E-01 -4.06799E-03  6.24541E+00  6.64722E-01  2.88827E+00
 -8.96009E-03 -3.45298E-03  1.80630E+00  4.96312E-02 -1.25237E+00 -9.73683E-01
 -1.27336E-01  6.24541E+00  4.96312E-02  2.89127E+02 -6.32071E+01  4.76679E+01
  1.96465E+01  6.64722E-01 -1.25237E+00 -5.02788E+00  2.45511E+04 -1.36128E+02
  1.74278E+00  2.88827E+00 -9.73683E-01 -2.23343E+02  8.52211E+02  9.00809E+03
Damping
  8.45063E-03 -8.26273E-04  1.36226E-02 -7.61951E-03  5.18934E+00  2.65689E-01
  1.61071E-03  1.34353E-01 -5.67013E-03  8.28248E-01  7.14761E-02 -3.13590E+00
 -9.49223E-04 -5.39011E-04  5.73438E-01  2.80449E-02  6.54793E+00 -1.07841E+00
 -7.61951E-03  8.28248E-01  2.80449E-02  2.87175E+01 -5.50224E+01 -8.14417E+01
  5.18934E+00  7.14761E-02  6.54793E+00  3.14031E+01  7.76622E+03 -4.01910E+02
  2.65689E-01 -3.13590E+00 -1.07841E+00 -1.11880E+02  5.86316E+02  2.16205E+03
Frequency     0.3590          Period       17.5000
Added Mass
  3.18158E-02 -3.31202E-03  1.18805E-02 -1.26052E-01  1.85441E+01  1.70299E+00
  7.72376E-03  9.18869E-01 -4.19851E-03  6.28170E+00  6.48179E-01  2.82785E+00
 -8.51112E-03 -3.29487E-03  1.75241E+00  5.24774E-02 -1.26189E+00 -9.90642E-01
 -1.26052E-01  6.28170E+00  5.24774E-02  2.89233E+02 -5.76304E+01  4.69279E+01
  1.85441E+01  6.48179E-01 -1.26189E+00 -3.32596E+00  2.36621E+04 -1.47711E+02
  1.70299E+00  2.82785E+00 -9.90642E-01 -2.19885E+02  7.72305E+02  9.19324E+03
Damping
  8.51269E-03 -8.73644E-04  1.31355E-02 -7.60378E-03  5.34153E+00  2.75132E-01
  1.65530E-03  1.51266E-01 -5.46255E-03  9.07773E-01  7.96096E-02 -3.11887E+00
 -9.15446E-04 -5.47366E-04  5.65935E-01  2.67844E-02  6.58276E+00 -1.04464E+00
 -7.60378E-03  9.07773E-01  2.67844E-02  2.94690E+01 -5.42798E+01 -8.19054E+01
  5.34153E+00  7.96096E-02  6.58276E+00  3.02630E+01  7.95372E+03 -3.84853E+02
  2.75132E-01 -3.11887E+00 -1.04464E+00 -1.15799E+02  5.86105E+02  2.31305E+03
Frequency     0.3696          Period       17.0000
Added Mass
  3.14638E-02 -3.15674E-03  1.26528E-02 -1.24692E-01  1.73769E+01  1.66086E+00
  7.43820E-03  9.09313E-01 -4.33670E-03  6.32012E+00  6.30662E-01  2.76389E+00
 -8.03575E-03 -3.12745E-03  1.69534E+00  5.54910E-02 -1.27198E+00 -1.00860E+00
 -1.24692E-01  6.32012E+00  5.54910E-02  2.89345E+02 -5.17255E+01  4.61446E+01
  1.73769E+01  6.30662E-01 -1.27198E+00 -1.52393E+00  2.27209E+04 -1.59976E+02
  1.66086E+00  2.76389E+00 -1.00860E+00 -2.16224E+02  6.87699E+02  9.38927E+03
Damping
  8.65441E-03 -9.23801E-04  1.26197E-02 -7.58712E-03  5.50081E+00  2.85130E-01
  1.70252E-03  1.69176E-01 -5.24277E-03  9.92048E-01  8.82215E-02 -3.10140E+00
 -8.79683E-04 -5.56211E-04  5.58153E-01  2.54504E-02  6.65061E+00 -1.00888E+00
 -7.58712E-03  9.92048E-01  2.54504E-02  3.03458E+01 -5.34934E+01 -8.24101E+01
  5.50081E+00  8.82215E-02  6.65061E+00  2.90559E+01  8.17439E+03 -3.66792E+02
  2.85130E-01 -3.10140E+00 -1.00888E+00 -1.19962E+02  5.85882E+02  2.47684E+03
Frequency     0.3808          Period       16.5000
Added Mass
  3.13083E-02 -3.01731E-03  1.37568E-02 -1.23919E-01  1.62788E+01  1.62801E+00
  7.21774E-03  8.89638E-01 -4.62271E-03  6.31562E+00  6.08092E-01  2.67835E+00
 -7.77255E-03 -3.01169E-03  1.65331E+00  5.87438E-02 -1.28546E+00 -1.05084E+00
 -1.23919E-01  6.31562E+00  5.87438E-02  2.89141E+02 -4.73804E+01  4.56713E+01
  1.62788E+01  6.08092E-01 -1.28546E+00  8.41501E-01  2.17401E+04 -1.85001E+02
  1.62801E+00  2.67835E+00 -1.05084E+00 -2.10672E+02  6.14990E+02  9.48738E+03
Damping
  8.60899E-03 -9.66010E-04  1.24679E-02 -7.55369E-03  5.53935E+00  2.93280E-01
  1.72720E-03  1.88610E-01 -5.13656E-03  1.09139E+00  9.49739E-02 -3.06006E+00
 -7.86765E-04 -5.42667E-04  5.46795E-01  2.50865E-02  6.61179E+00 -9.94466E-01
 -7.55369E-03  1.09139E+00  2.50865E-02  3.10606E+01 -5.25258E+01 -8.23678E+01
  5.53935E+00  9.49739E-02  6.61179E+00  2.86501E+01  8.26455E+03 -3.57107E+02
  2.93280E-01 -3.06006E+00 -9.94466E-01 -1.23585E+02  5.79777E+02  2.69129E+03
Frequency     0.3927          Period       16.0000
Added Mass
  3.11429E-02 -2.86918E-03  1.49298E-02 -1.23096E-01  1.51121E+01  1.59309E+00
  6.98352E-03  8.68733E-01 -4.92660E-03  6.31083E+00  5.84112E-01  2.58746E+00
 -7.49290E-03 -2.88869E-03  1.60866E+00  6.21998E-02 -1.29974E+00 -1.09572E+00
 -1.23096E-01  6.31083E+00  6.21998E-02  2.88924E+02 -4.27636E+01  4.51685E+01
  1.51121E+01  5.84112E-01 -1.29974E+00  3.35477E+00  2.06979E+04 -2.11590E+02
  1.59309E+00  2.58746E+00 -1.09572E+00 -2.04775E+02  5.37738E+02  9.59162E+03
Damping
  8.65221E-03 -1.01086E-03  1.23066E-02 -7.51816E-03  5.57806E+00  3.01940E-01
  1.75342E-03  2.09249E-01 -5.02371E-03  1.19670E+00  1.02148E-01 -3.01427E+00
 -6.88039E-04 -5.28276E-04  5.34882E-01  2.47005E-02  6.60030E+00 -9.79148E-01
 -7.51816E-03  1.19670E+00  2.47005E-02  3.19009E+01 -5.14977E+01 -8.22772E+01
  5.57806E+00  1.02148E-01  6.60030E+00  2.82190E+01  8.37531E+03 -3.46816E+02
  3.01940E-01 -3.01427E+00 -9.79148E-01 -1.27387E+02  5.73289E+02  2.91874E+03
Frequency     0.4054          Period       15.5000
Added Mass
  3.13108E-02 -2.75575E-03  1.56496E-02 -1.22880E-01  1.42278E+01  1.57113E+00
  6.85784E-03  8.37484E-01 -5.12548E-03  6.24905E+00  5.60743E-01  2.48912E+00
 -7.48317E-03 -2.85076E-03  1.57888E+00  6.39519E-02 -1.25467E+00 -1.11289E+00
 -1.22880E-01  6.24905E+00  6.39519E-02  2.88327E+02 -3.95514E+01  4.52491E+01
  1.42278E+01  5.60743E-01 -1.25467E+00  4.81996E+00  1.97130E+04 -2.31690E+02
  1.57113E+00  2.48912E+00 -1.11289E+00 -1.97148E+02  4.79360E+02  9.48482E+03
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Damping
  8.53928E-03 -1.06271E-03  1.25980E-02 -7.72353E-03  5.47612E+00  3.13216E-01
  1.77790E-03  2.29884E-01 -5.04341E-03  1.31297E+00  1.06449E-01 -2.93911E+00
 -5.93888E-04 -5.09295E-04  5.20880E-01  2.52960E-02  6.47730E+00 -9.87900E-01
 -7.72353E-03  1.31297E+00  2.52960E-02  3.24973E+01 -5.03435E+01 -8.12786E+01
  5.47612E+00  1.06449E-01  6.47730E+00  2.86256E+01  8.31789E+03 -3.46930E+02
  3.13216E-01 -2.93911E+00 -9.87900E-01 -1.30186E+02  5.59816E+02  3.19618E+03
Frequency     0.4189          Period       15.0000
Added Mass
  3.14899E-02 -2.63476E-03  1.64174E-02 -1.22650E-01  1.32846E+01  1.54770E+00
  6.72378E-03  8.04150E-01 -5.33761E-03  6.18315E+00  5.35816E-01  2.38422E+00
 -7.47280E-03 -2.81029E-03  1.54712E+00  6.58208E-02 -1.20663E+00 -1.13120E+00
 -1.22650E-01  6.18315E+00  6.58208E-02  2.87690E+02 -3.61249E+01  4.53352E+01
  1.32846E+01  5.35816E-01 -1.20663E+00  6.38284E+00  1.86624E+04 -2.53131E+02
  1.54770E+00  2.38422E+00 -1.13120E+00 -1.89013E+02  4.17089E+02  9.37090E+03
Damping
  8.52666E-03 -1.11802E-03  1.29087E-02 -7.94259E-03  5.36475E+00  3.25243E-01
  1.80401E-03  2.51862E-01 -5.06442E-03  1.43618E+00  1.11037E-01 -2.85260E+00
 -4.93460E-04 -4.89048E-04  5.06071E-01  2.59318E-02  6.37022E+00 -9.97236E-01
 -7.94259E-03  1.43618E+00  2.59318E-02  3.32071E+01 -4.91123E+01 -8.00591E+01
  5.36475E+00  1.11037E-01  6.37022E+00  2.90595E+01  8.25780E+03 -3.47051E+02
  3.25243E-01 -2.85260E+00 -9.97236E-01 -1.33017E+02  5.45445E+02  3.48418E+03
Frequency     0.4333          Period       14.5000
Added Mass
  3.19226E-02 -2.51648E-03  1.63247E-02 -1.22448E-01  1.26986E+01  1.52728E+00
  6.66586E-03  7.63776E-01 -5.33440E-03  6.07069E+00  5.14417E-01  2.27341E+00
 -7.62028E-03 -2.82691E-03  1.52426E+00  6.54500E-02 -1.10533E+00 -1.10202E+00
 -1.22448E-01  6.07069E+00  6.54500E-02  2.86747E+02 -3.37554E+01  4.55661E+01
  1.26986E+01  5.14417E-01 -1.10533E+00  6.39294E+00  1.77392E+04 -2.58442E+02
  1.52728E+00  2.27341E+00 -1.10202E+00 -1.79759E+02  3.75218E+02  9.02651E+03
Damping
  8.50208E-03 -1.20037E-03  1.34812E-02 -8.60416E-03  5.17674E+00  3.44492E-01
  1.85989E-03  2.73070E-01 -5.15820E-03  1.56455E+00  1.14271E-01 -2.73090E+00
 -4.57814E-04 -4.88024E-04  4.90347E-01  2.69384E-02  6.20142E+00 -1.01591E+00
 -8.60416E-03  1.56455E+00  2.69384E-02  3.37018E+01 -4.78287E+01 -7.76914E+01
  5.17674E+00  1.14271E-01  6.20142E+00  2.98913E+01  8.05373E+03 -3.53177E+02
  3.44492E-01 -2.73090E+00 -1.01591E+00 -1.34756E+02  5.26760E+02  3.78528E+03
Frequency     0.4488          Period       14.0000
Added Mass
  3.24288E-02 -2.35169E-03  1.54932E-02 -1.21694E-01  1.23770E+01  1.49839E+00
  6.62007E-03  7.19040E-01 -5.14536E-03  5.92832E+00  4.94951E-01  2.14459E+00
 -7.78598E-03 -2.85103E-03  1.50526E+00  6.35140E-02 -1.00062E+00 -1.03903E+00
 -1.21694E-01  5.92832E+00  6.35140E-02  2.85597E+02 -3.19794E+01  4.53384E+01
  1.23770E+01  4.94951E-01 -1.00062E+00  5.22421E+00  1.69431E+04 -2.49598E+02
  1.49839E+00  2.14459E+00 -1.03903E+00 -1.69754E+02  3.47462E+02  8.51656E+03
Damping
  8.56693E-03 -1.31215E-03  1.40918E-02 -9.65088E-03  4.98663E+00  3.70560E-01
  1.95853E-03  2.93822E-01 -5.26758E-03  1.69638E+00  1.17760E-01 -2.57359E+00
 -5.00630E-04 -5.15634E-04  4.73896E-01  2.77884E-02  6.00607E+00 -1.03169E+00
 -9.65088E-03  1.69638E+00  2.77884E-02  3.40579E+01 -4.65844E+01 -7.42364E+01
  4.98663E+00  1.17760E-01  6.00607E+00  3.07470E+01  7.75382E+03 -3.60594E+02
  3.70560E-01 -2.57359E+00 -1.03169E+00 -1.35570E+02  5.07373E+02  4.06587E+03
Frequency     0.4654          Period       13.5000
Added Mass
  3.28517E-02 -2.08514E-03  1.39805E-02 -1.19877E-01  1.22783E+01  1.45222E+00
  6.52904E-03  6.70501E-01 -4.76579E-03  5.75975E+00  4.75675E-01  1.97635E+00
 -7.85073E-03 -2.83246E-03  1.48898E+00  6.05003E-02 -9.37256E-01 -9.51239E-01
 -1.19877E-01  5.75975E+00  6.05003E-02  2.84256E+02 -3.05774E+01  4.39305E+01
  1.22783E+01  4.75675E-01 -9.37256E-01  3.03342E+00  1.63085E+04 -2.26919E+02
  1.45222E+00  1.97635E+00 -9.51239E-01 -1.59168E+02  3.31005E+02  7.87508E+03
Damping
  8.75863E-03 -1.44621E-03  1.45645E-02 -1.09673E-02  4.85181E+00  4.01512E-01
  2.11090E-03  3.14064E-01 -5.35040E-03  1.83165E+00  1.22399E-01 -2.38018E+00
 -6.31854E-04 -5.78725E-04  4.56521E-01  2.80728E-02  5.78253E+00 -1.03644E+00
 -1.09673E-02  1.83165E+00  2.80728E-02  3.42670E+01 -4.54460E+01 -6.97045E+01
  4.85181E+00  1.22399E-01  5.78253E+00  3.13539E+01  7.37491E+03 -3.65963E+02
  4.01512E-01 -2.38018E+00 -1.03644E+00 -1.35328E+02  4.89614E+02  4.29564E+03
Frequency     0.4833          Period       13.0000
Added Mass
  3.30074E-02 -1.67586E-03  1.20979E-02 -1.16767E-01  1.22861E+01  1.38555E+00
  6.32279E-03  6.17964E-01 -4.24673E-03  5.56557E+00  4.52809E-01  1.74951E+00
 -7.68349E-03 -2.70824E-03  1.47464E+00  5.74988E-02 -9.47689E-01 -8.56391E-01
 -1.16767E-01  5.56557E+00  5.74988E-02  2.82730E+02 -2.93131E+01  4.07638E+01
  1.22861E+01  4.52809E-01 -9.47689E-01  3.73518E-01  1.58378E+04 -1.95234E+02
  1.38555E+00  1.74951E+00 -8.56391E-01 -1.48132E+02  3.20809E+02  7.17235E+03
Damping
  9.03783E-03 -1.56858E-03  1.47111E-02 -1.22106E-02  4.82221E+00  4.31953E-01
  2.30977E-03  3.33551E-01 -5.34866E-03  1.96667E+00  1.28655E-01 -2.11316E+00
 -8.12320E-04 -6.63300E-04  4.37231E-01  2.74698E-02  5.43437E+00 -1.02342E+00
 -1.22106E-02  1.96667E+00  2.74698E-02  3.40405E+01 -4.43745E+01 -6.32827E+01
  4.82221E+00  1.28655E-01  5.43437E+00  3.14319E+01  6.90798E+03 -3.65372E+02
  4.31953E-01 -2.11316E+00 -1.02342E+00 -1.32734E+02  4.74632E+02  4.43121E+03
Frequency     0.5027          Period       12.5000
Added Mass
  3.27512E-02 -1.15434E-03  1.04132E-02 -1.12856E-01  1.22423E+01  1.30602E+00
  5.95431E-03  5.60426E-01 -3.73342E-03  5.33814E+00  4.20722E-01  1.46441E+00
 -7.26265E-03 -2.45504E-03  1.46239E+00  5.60253E-02 -1.03056E+00 -7.78953E-01
 -1.12856E-01  5.33814E+00  5.60253E-02  2.81001E+02 -2.82434E+01  3.60138E+01
  1.22423E+01  4.20722E-01 -1.03056E+00 -1.81509E+00  1.55002E+04 -1.64641E+02
  1.30602E+00  1.46441E+00 -7.78953E-01 -1.36849E+02  3.13352E+02  6.49525E+03
Damping
  9.22566E-03 -1.62056E-03  1.44406E-02 -1.29183E-02  4.91366E+00  4.55375E-01
  2.52015E-03  3.50942E-01 -5.21101E-03  2.08231E+00  1.34966E-01 -1.61820E+00
 -9.31897E-04 -7.21451E-04  4.13560E-01  2.60589E-02  4.64361E+00 -9.90412E-01
 -1.29183E-02  2.08231E+00  2.60589E-02  3.23388E+01 -4.32697E+01 -5.13556E+01
  4.91366E+00  1.34966E-01  4.64361E+00  3.08960E+01  6.26029E+03 -3.56067E+02
  4.55375E-01 -1.61820E+00 -9.90412E-01 -1.23318E+02  4.62205E+02  4.40113E+03
Frequency     0.5236          Period       12.0000
Added Mass
  3.21008E-02 -6.57069E-04  9.50561E-03 -1.09369E-01  1.20140E+01  1.23022E+00
  5.44194E-03  4.97179E-01 -3.42758E-03  5.06047E+00  3.77721E-01  1.15596E+00
 -6.82093E-03 -2.15819E-03  1.45387E+00  5.70535E-02 -1.15202E+00 -7.43038E-01
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 -1.09369E-01  5.06047E+00  5.70535E-02  2.79007E+02 -2.76236E+01  3.11139E+01
  1.20140E+01  3.77721E-01 -1.15202E+00 -2.77329E+00  1.52482E+04 -1.47210E+02
  1.23022E+00  1.15596E+00 -7.43038E-01 -1.25781E+02  3.07047E+02  5.90114E+03
Damping
  9.42003E-03 -1.55377E-03  1.39057E-02 -1.28210E-02  5.07933E+00  4.68820E-01
  2.68484E-03  3.65755E-01 -4.95075E-03  2.20087E+00  1.35108E-01 -1.10475E+00
 -8.64095E-04 -6.93749E-04  3.86399E-01  2.46220E-02  3.73966E+00 -9.44262E-01
 -1.28210E-02  2.20087E+00  2.46220E-02  3.05732E+01 -4.22064E+01 -3.90272E+01
  5.07933E+00  1.35108E-01  3.73966E+00  3.00915E+01  5.61510E+03 -3.39197E+02
  4.68820E-01 -1.10475E+00 -9.44262E-01 -1.11331E+02  4.52575E+02  4.32844E+03
Frequency     0.5464          Period       11.5000
Added Mass
  3.13694E-02 -3.71723E-04  9.44661E-03 -1.07746E-01  1.15730E+01  1.17424E+00
  4.88563E-03  4.29930E-01 -3.41500E-03  4.71779E+00  3.38976E-01  8.97022E-01
 -6.77660E-03 -1.98158E-03  1.45171E+00  5.97785E-02 -1.25875E+00 -7.53747E-01
 -1.07746E-01  4.71779E+00  5.97785E-02  2.76670E+02 -2.71726E+01  2.81811E+01
  1.15730E+01  3.38976E-01 -1.25875E+00 -2.73951E+00  1.50458E+04 -1.48860E+02
  1.17424E+00  8.97022E-01 -7.53747E-01 -1.15669E+02  2.96997E+02  5.36015E+03
Damping
  1.02395E-02 -1.38992E-03  1.35216E-02 -1.22199E-02  5.20898E+00  4.76855E-01
  2.74719E-03  3.80673E-01 -4.66747E-03  2.43473E+00  1.20919E-01 -1.56607E+00
 -6.30683E-04 -5.74144E-04  3.64283E-01  2.43472E-02  4.37952E+00 -9.03212E-01
 -1.22199E-02  2.43473E+00  2.43472E-02  3.46563E+01 -4.14129E+01 -4.99966E+01
  5.20898E+00  1.20919E-01  4.37952E+00  2.95950E+01  5.68650E+03 -3.20727E+02
  4.76855E-01 -1.56607E+00 -9.03212E-01 -1.20569E+02  4.46065E+02  4.69022E+03
Frequency     0.5712          Period       11.0000
Added Mass
  3.23525E-02 -4.24868E-04  8.01375E-03 -1.08491E-01  1.11152E+01  1.17132E+00
  4.68227E-03  3.64214E-01 -3.34019E-03  4.32016E+00  3.43358E-01  7.97034E-01
 -7.05854E-03 -1.99189E-03  1.45848E+00  6.01809E-02 -1.31870E+00 -7.30703E-01
 -1.08491E-01  4.32016E+00  6.01809E-02  2.73964E+02 -2.63082E+01  2.88069E+01
  1.11152E+01  3.43358E-01 -1.31870E+00 -3.41930E+00  1.48667E+04 -1.50392E+02
  1.17132E+00  7.97034E-01 -7.30703E-01 -1.06585E+02  2.84723E+02  4.72867E+03
Damping
  1.01014E-02 -1.21674E-03  1.44960E-02 -1.01586E-02  5.02989E+00  4.55315E-01
  2.52335E-03  3.85903E-01 -4.74070E-03  2.57208E+00  9.82368E-02 -1.49359E+00
 -5.25848E-04 -4.01942E-04  3.36096E-01  2.99918E-02  3.95211E+00 -9.49174E-01
 -1.01586E-02  2.57208E+00  2.99918E-02  3.50457E+01 -4.02684E+01 -4.68983E+01
  5.02989E+00  9.82368E-02  3.95211E+00  3.16305E+01  5.25452E+03 -3.29687E+02
  4.55315E-01 -1.49359E+00 -9.49174E-01 -1.15200E+02  4.29786E+02  4.84642E+03
Frequency     0.5984          Period       10.5000
Added Mass
  2.99819E-02  4.98097E-06  9.54475E-03 -1.01821E-01  1.02737E+01  9.82826E-01
  3.84971E-03  3.06334E-01 -4.28643E-03  3.92033E+00  3.40162E-01  7.48809E-01
 -6.67192E-03 -1.82124E-03  1.47672E+00  7.09082E-02 -1.71707E+00 -8.90360E-01
 -1.01821E-01  3.92033E+00  7.09082E-02  2.71023E+02 -2.62352E+01  2.82621E+01
  1.02737E+01  3.40162E-01 -1.71707E+00  2.12143E+00  1.45358E+04 -2.15187E+02
  9.82826E-01  7.48809E-01 -8.90360E-01 -9.81609E+01  2.62612E+02  3.94577E+03
Damping
  1.05496E-02 -1.27758E-03  1.48496E-02 -1.69834E-02  5.11118E+00  5.17178E-01
  2.48216E-03  3.83971E-01 -4.70916E-03  2.64363E+00  1.00957E-01 -1.21358E+00
 -1.38772E-03 -4.76508E-04  3.03580E-01  2.77417E-02  3.44464E+00 -9.52043E-01
 -1.69834E-02  2.64363E+00  2.77417E-02  3.40801E+01 -3.91442E+01 -3.83120E+01
  5.11118E+00  1.00957E-01  3.44464E+00  3.11687E+01  4.73846E+03 -3.31048E+02
  5.17178E-01 -1.21358E+00 -9.52043E-01 -1.04832E+02  4.08194E+02  4.88544E+03
Frequency     0.6283          Period       10.0000
Added Mass
  3.09198E-02 -7.73312E-04  8.64336E-03 -1.02428E-01  1.04526E+01  9.38473E-01
  4.18342E-03  2.55049E-01 -4.56069E-03  3.54587E+00  5.22877E-01  6.70311E-01
 -7.61654E-03 -2.78322E-03  1.49394E+00  5.60632E-02 -1.64785E+00 -8.67373E-01
 -1.02428E-01  3.54587E+00  5.60632E-02  2.67983E+02 -1.92518E+01  2.69883E+01
  1.04526E+01  5.22877E-01 -1.64785E+00 -1.31847E-01  1.45958E+04 -2.29630E+02
  9.38473E-01  6.70311E-01 -8.67373E-01 -8.89108E+01  1.94992E+02  3.19075E+03
Damping
  1.29058E-02 -1.44801E-03  1.36045E-02 -2.08474E-02  5.90089E+00  6.41725E-01
  3.27170E-03  3.80247E-01 -4.00754E-03  2.71112E+00  3.80654E-02 -1.04372E+00
 -3.06053E-03 -5.66635E-04  2.65461E-01  2.14681E-02  3.43468E+00 -7.78967E-01
 -2.08474E-02  2.71112E+00  2.14681E-02  3.38874E+01 -4.14078E+01 -3.27650E+01
  5.90089E+00  3.80654E-02  3.43468E+00  2.69347E+01  4.58169E+03 -2.71635E+02
  6.41725E-01 -1.04372E+00 -7.78967E-01 -9.65054E+01  4.36952E+02  4.83214E+03
Frequency     0.6614          Period        9.5000
Added Mass
  3.32336E-02  4.64680E-04  4.44992E-03 -1.04500E-01  1.17335E+01  1.14783E+00
  5.00367E-03  2.08187E-01 -2.94573E-03  3.26364E+00  3.27247E-01  3.52841E-01
 -1.13221E-02 -1.71165E-03  1.50279E+00  4.66241E-02 -1.38268E+00 -6.07600E-01
 -1.04500E-01  3.26364E+00  4.66241E-02  2.68003E+02 -2.88343E+01  1.69965E+01
  1.17335E+01  3.27247E-01 -1.38268E+00 -1.15888E+01  1.51946E+04 -1.31116E+02
  1.14783E+00  3.52841E-01 -6.07600E-01 -9.70612E+01  3.13860E+02  2.65293E+03
Damping
  1.26876E-02 -1.28366E-03  1.25686E-02 -1.37930E-02  5.79241E+00  6.05985E-01
  3.37647E-03  3.76751E-01 -3.96356E-03  2.81943E+00  9.10686E-02 -6.81339E-01
 -3.44670E-03 -9.10502E-04  2.27877E-01  2.85997E-02  2.59090E+00 -7.70593E-01
 -1.37930E-02  2.81943E+00  2.85997E-02  3.34109E+01 -3.69241E+01 -2.29546E+01
  5.79241E+00  9.10686E-02  2.59090E+00  2.85375E+01  3.98106E+03 -2.62114E+02
  6.05985E-01 -6.81339E-01 -7.70593E-01 -8.88981E+01  4.05589E+02  4.54024E+03
Frequency     0.6981          Period        9.0000
Added Mass
  3.00809E-02 -7.63017E-04  3.77092E-03 -9.13926E-02  1.06422E+01  9.64050E-01
  3.75143E-03  1.61434E-01 -3.34635E-03  2.84319E+00  4.87646E-01  5.41648E-01
 -1.04422E-02 -3.29852E-03  1.53226E+00  6.80672E-02 -1.88262E+00 -7.67885E-01
 -9.13926E-02  2.84319E+00  6.80672E-02  2.64827E+02 -1.33636E+01  2.34626E+01
  1.06422E+01  4.87646E-01 -1.88262E+00 -1.17958E+01  1.51100E+04 -1.45338E+02
  9.64050E-01  5.41648E-01 -7.67885E-01 -1.01095E+02  1.88500E+02  2.17974E+03
Damping
  1.19343E-02 -8.68038E-04  1.44695E-02 -1.17275E-02  4.92690E+00  5.14861E-01
  2.77956E-03  3.66841E-01 -5.11304E-03  2.92327E+00  3.14884E-03 -7.08897E-01
 -3.41970E-03 -2.26143E-04  2.00882E-01  3.63815E-02  1.85465E+00 -1.02545E+00
 -1.17275E-02  2.92327E+00  3.63815E-02  3.52534E+01 -4.14187E+01 -2.25916E+01
  4.92690E+00  3.14884E-03  1.85465E+00  3.52579E+01  3.22693E+03 -3.42440E+02
  5.14861E-01 -7.08897E-01 -1.02545E+00 -8.53902E+01  4.09326E+02  4.43552E+03
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Frequency     0.7392          Period        8.5000
Added Mass
  2.80733E-02  8.63180E-04  3.94948E-03 -9.76744E-02  9.40978E+00  7.12502E-01
  3.00569E-03  1.26849E-01 -4.74287E-03  2.42675E+00  3.20932E-01  4.28628E-01
 -1.16362E-02 -1.34519E-03  1.57127E+00  5.73617E-02 -2.19017E+00 -8.91420E-01
 -9.76744E-02  2.42675E+00  5.73617E-02  2.60423E+02 -2.75239E+01  1.97700E+01
  9.40978E+00  3.20932E-01 -2.19017E+00 -1.41743E+01  1.49239E+04 -2.86020E+02
  7.12502E-01  4.28628E-01 -8.91420E-01 -9.43804E+01  2.42695E+02  1.68612E+03
Damping
  1.68517E-02 -7.65326E-04  1.24771E-02 -3.20571E-02  6.29197E+00  8.16220E-01
  3.78437E-03  3.49193E-01 -3.82260E-03  2.90077E+00  9.36844E-02 -4.76695E-01
 -8.78713E-03 -9.02888E-04  1.54689E-01  2.60920E-02  1.92816E+00 -7.79085E-01
 -3.20571E-02  2.90077E+00  2.60920E-02  3.48348E+01 -3.81719E+01 -1.57515E+01
  6.29197E+00  9.36844E-02  1.92816E+00  2.69571E+01  3.29399E+03 -2.53231E+02
  8.16220E-01 -4.76695E-01 -7.79085E-01 -7.15962E+01  3.94129E+02  4.29959E+03
Frequency     0.7854          Period        8.0000
Added Mass
  3.25899E-02  6.12879E-04  1.95051E-03 -9.78140E-02  1.07846E+01  9.69802E-01
  3.89621E-03  9.78707E-02 -1.60488E-03  2.05961E+00  2.81571E-01  3.56519E-01
 -1.63861E-02 -1.42288E-03  1.58848E+00  4.77994E-02 -1.58553E+00 -3.85180E-01
 -9.78140E-02  2.05961E+00  4.77994E-02  2.55911E+02 -2.18974E+01  1.74670E+01
  1.07846E+01  2.81571E-01 -1.58553E+00 -3.99941E+01  1.57877E+04 -1.14057E+02
  9.69802E-01  3.56519E-01 -3.85180E-01 -9.12730E+01  2.59877E+02  1.32269E+03
Damping
  1.58384E-02 -6.97224E-04  1.06463E-02 -8.64183E-03  5.28830E+00  7.20634E-01
  3.99988E-03  3.32010E-01 -4.55187E-03  2.91533E+00  8.25513E-02 -4.22885E-01
 -1.03233E-02 -1.16385E-03  1.16191E-01  4.72218E-02  6.93452E-01 -9.38232E-01
 -8.64183E-03  2.91533E+00  4.72218E-02  3.55179E+01 -3.48749E+01 -1.38361E+01
  5.28830E+00  8.25513E-02  6.93452E-01  3.09171E+01  2.59163E+03 -2.78834E+02
  7.20634E-01 -4.22885E-01 -9.38232E-01 -6.75596E+01  3.72075E+02  4.02113E+03
Frequency     0.8378          Period        7.5000
Added Mass
  2.28553E-02 -1.85538E-04  3.04654E-03 -9.57227E-02  7.84818E+00  3.36698E-01
  1.16386E-03  7.47385E-02 -4.49692E-03  1.71895E+00  6.50217E-01  5.00637E-01
 -1.91058E-02 -5.45030E-03  1.66107E+00  6.07083E-02 -3.04060E+00 -8.42276E-01
 -9.57227E-02  1.71895E+00  6.07083E-02  2.53298E+02  8.14537E+00  2.00189E+01
  7.84818E+00  6.50217E-01 -3.04060E+00 -6.65578E+01  1.47677E+04 -2.57960E+02
  3.36698E-01  5.00637E-01 -8.42276E-01 -9.61923E+01 -8.08959E+01  1.01871E+03
Damping
  2.13918E-02 -7.23297E-04  8.96779E-03 -3.86796E-02  5.70936E+00  9.72087E-01
  4.43046E-03  3.08096E-01 -3.97654E-03  2.82038E+00 -3.33576E-02 -3.95741E-01
 -2.78249E-02 -7.95745E-04  3.49437E-02  2.80179E-02  3.31299E-02 -8.29563E-01
 -3.86796E-02  2.82038E+00  2.80179E-02  3.43009E+01 -4.36389E+01 -1.19496E+01
  5.70936E+00 -3.33576E-02  3.31299E-02  7.01394E+00  2.92406E+03 -2.87481E+02
  9.72087E-01 -3.95741E-01 -8.29563E-01 -5.16789E+01  4.13749E+02  3.77612E+03
Frequency     0.8976          Period        7.0000
Added Mass
  2.27598E-02 -2.09912E-04  3.10860E-03 -9.25059E-02  4.15935E+00  5.31609E-01
  1.87978E-03  5.67751E-02 -2.11696E-04  1.41354E+00  3.72653E-01  5.00621E-01
  1.05601E-02 -4.94090E-03  1.61285E+00  7.41648E-02 -5.54724E-01 -9.17830E-02
 -9.25059E-02  1.41354E+00  7.41648E-02  2.50130E+02  1.30313E+01  1.95754E+01
  4.15935E+00  3.72653E-01 -5.54724E-01 -4.32436E+01  1.63913E+04  3.20434E+02
  5.31609E-01  5.00621E-01 -9.17830E-02 -1.04034E+02 -3.84631E+01  8.08937E+02
Damping
  1.40236E-02 -2.65918E-04  5.59421E-03 -7.26666E-03  3.09687E+00  6.81767E-01
  3.41714E-03  2.80586E-01 -4.96153E-03  2.63786E+00  4.15255E-01 -2.75812E-01
 -9.10605E-03  1.12684E-03  2.38118E-01  7.80188E-02  1.87596E+00 -1.10643E+00
 -7.26666E-03  2.63786E+00  7.80188E-02  3.15755E+01 -3.15291E+01 -8.93043E+00
  3.09687E+00  4.15255E-01  1.87596E+00  7.04482E+01  8.33344E+02 -3.78205E+02
  6.81767E-01 -2.75812E-01 -1.10643E+00 -3.08566E+01  2.84732E+02  3.39173E+03
Frequency     0.9666          Period        6.5000
Added Mass
  2.72364E-02  8.49546E-05  5.71027E-03 -1.45944E-01  9.41632E+00  9.26348E-01
  4.00140E-03  4.11587E-02  1.80764E-03  1.27370E+00  2.97903E-01  4.15086E-01
  1.30844E-02 -1.57777E-03  1.78581E+00  4.67002E-02 -1.94219E+00  3.80447E-01
 -1.45944E-01  1.27370E+00  4.67002E-02  2.52976E+02 -1.48923E+01  1.72567E+01
  9.41632E+00  2.97903E-01 -1.94219E+00 -5.10592E+01  1.62515E+04  2.31358E+02
  9.26348E-01  4.15086E-01  3.80447E-01 -1.48243E+02  2.13815E+02  6.39060E+02
Damping
  1.84134E-02 -1.54527E-04  5.52332E-03  4.56218E-02  2.19146E+00  7.74509E-01
  4.32415E-03  2.42063E-01 -4.12701E-03  2.15696E+00  2.36376E-01 -1.82973E-01
  3.57947E-02 -1.90174E-03  1.76497E-01  1.56801E-01 -7.80072E-01 -9.35818E-01
  4.56218E-02  2.15696E+00  1.56801E-01  2.21175E+01 -1.11942E+01 -8.52324E+00
  2.19146E+00  2.36376E-01 -7.80072E-01  9.82843E+01 -1.27878E+03 -8.10749E+01
  7.74509E-01 -1.82973E-01 -9.35818E-01  1.87888E+01  1.97512E+02  2.97565E+03
Frequency     1.0472          Period        6.0000
Added Mass
  1.48401E-02 -7.13785E-04  9.14864E-03 -5.63700E-02  7.92650E+00  1.20385E+00
  4.72449E-03  1.18230E-01 -2.97489E-03  6.67746E-01  3.47737E-01  6.84910E-01
  7.31857E-03 -2.90824E-03  1.80175E+00  1.23967E-01 -3.70575E-01  3.39422E-01
 -5.63700E-02  6.67746E-01  1.23967E-01  2.19832E+02 -2.25489E+01  2.30506E+01
  7.92650E+00  3.47737E-01 -3.70575E-01  3.03478E+00  1.67611E+04  5.97381E+01
  1.20385E+00  6.84910E-01  3.39422E-01  2.56998E+01  1.98694E+02  7.45786E+02
Damping
  3.59302E-02  2.91382E-05  1.86478E-02  4.76644E-02  1.10351E+01  9.23918E-01
  2.32961E-03  2.55714E-01 -7.26450E-03  4.49639E+00  3.94511E-01 -6.69360E-02
 -1.00444E-02 -2.58284E-03  1.05605E-01  6.17754E-02  3.38919E+00 -1.54295E+00
  4.76644E-02  4.49639E+00  6.17754E-02  9.19516E+01 -2.91544E+01 -4.32650E-01
  1.10351E+01  3.94511E-01  3.38919E+00  1.72208E+01  2.31420E+03 -4.08297E+02
  9.23918E-01 -6.69360E-02 -1.54295E+00 -3.78927E+02  2.99029E+02  2.90795E+03
Frequency     1.1424          Period        5.5000
Added Mass
  8.32758E-03 -2.07147E-05  7.48124E-03 -6.28347E-02  5.18832E+00  9.79946E-02
  3.32258E-04  6.64511E-02 -3.40531E-03  6.29861E-01  6.80612E-02  4.49918E-01
  5.26156E-03 -9.36111E-04  1.81270E+00  1.02070E-01 -1.78031E+00 -5.82505E-01
 -6.28347E-02  6.29861E-01  1.02070E-01  2.31107E+02 -3.00673E+01  1.89244E+01
  5.18832E+00  6.80612E-02 -1.78031E+00  7.25954E+00  1.64153E+04 -2.11300E+02
  9.79946E-02  4.49918E-01 -5.82505E-01 -5.61786E+01  3.06378E+02  6.95440E+02
Damping
  1.61228E-02 -2.48315E-04  9.94372E-03 -6.88605E-02  4.63533E+00  4.19393E-01
  1.19887E-03  1.92977E-01 -2.21489E-03  2.45826E+00  2.12053E-01 -1.16811E-01
 -1.78245E-03 -1.07972E-03  5.30935E-02  1.05383E-01  6.38060E-01 -6.77998E-01
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-6.88605E-02	2.45826E+00	1.05383E-01	4.25079E+01	-4.39530E+00	-5.75075E+00
4.63533E+00	2.12053E-01	6.38060E-01	-5.93486E+00	5.97214E+02	-1.26232E+02
4.19393E-01	-1.16811E-01	-6.77998E-01	-8.43965E+01	3.05318E+01	2.33075E+03

Frequency 1.2566 Period 5.0000

Added Mass

1.03830E-02	4.91671E-04	7.27895E-03	-1.27004E-01	6.72756E+00	1.47823E-01
2.17962E-04	6.88590E-02	-2.04251E-03	5.89715E-01	1.56828E-01	4.27326E-01
-2.09221E-03	-8.09047E-04	1.87642E+00	-1.17457E-02	-1.43552E+00	-4.75581E-01
-1.27004E-01	5.89715E-01	-1.17457E-02	2.28139E+02	-4.04829E+01	2.37000E+01
6.72756E+00	1.56828E-01	-1.43552E+00	-8.86343E+00	1.76332E+04	-1.35889E+02
1.47823E-01	4.27326E-01	-4.75581E-01	-7.08877E+01	2.93977E+02	7.47875E+02

Damping

2.05123E-02	-3.49948E-04	1.44981E-02	-2.14023E-01	6.30833E+00	8.82718E-01
6.17681E-03	1.46446E-01	-3.00108E-03	1.80620E+00	4.92390E-02	-1.76056E-01
-6.15284E-03	-1.42610E-04	7.16985E-02	2.25649E-01	7.71907E-01	-4.71135E-01
-2.14023E-01	1.80620E+00	2.25649E-01	3.13171E+01	-6.44725E+01	2.66326E+00
6.30833E+00	4.92390E-02	7.71907E-01	3.33431E+01	1.24735E+03	-2.85812E+02
8.82718E-01	-1.76056E-01	-4.71135E-01	-3.21877E+01	3.93145E+02	1.76333E+03

Frequency 1.3963 Period 4.5000

Added Mass

1.17857E-02	-2.50681E-04	5.94902E-03	1.71179E-01	4.20011E+00	-3.88818E-01
-2.95130E-03	9.72196E-02	5.99741E-04	1.03000E+00	-7.15764E-01	6.54082E-01
1.55977E-02	-4.50126E-04	1.86889E+00	-3.03840E-01	2.18889E+00	-1.16165E-01
1.71179E-01	1.03000E+00	-3.03840E-01	2.40645E+02	-9.81773E+00	1.91800E+01
4.20011E+00	-7.15764E-01	2.18889E+00	-5.80687E+01	1.77520E+04	3.77845E+01
-3.88818E-01	6.54082E-01	-1.16165E-01	-1.75063E+02	2.98104E+02	9.77820E+02

Damping

1.06309E-02	-1.39684E-03	6.72341E-03	-3.64339E-02	3.76907E+00	-6.97267E-01
-5.40128E-03	1.15700E-02	1.12453E-02	2.65500E-01	-5.89509E-01	-6.64773E-01
9.02918E-03	6.88611E-03	1.06387E-02	7.99912E-03	-1.04365E+00	1.48483E+00
-3.64339E-02	2.65500E-01	7.99912E-03	7.21234E+00	1.91863E+01	1.23188E+01
3.76907E+00	-5.89509E-01	-1.04365E+00	-3.76944E+01	-2.29908E+02	1.48096E+02
-6.97267E-01	-6.64773E-01	1.48483E+00	-2.67886E+01	-2.49992E+02	3.12539E+02

Frequency 1.5708 Period 4.0000

Added Mass

2.09485E-02	3.44098E-03	1.82888E-03	1.97351E-01	4.75090E+00	7.00368E-01
4.72585E-03	1.29409E-01	-7.98886E-03	1.00563E+00	8.19638E-01	8.42483E-01
1.05342E-02	-2.67884E-03	1.88953E+00	-2.41185E-01	1.82660E+00	-1.28900E+00
1.97351E-01	1.00563E+00	-2.41185E-01	2.32363E+02	-1.71762E+01	1.42548E+00
4.75090E+00	8.19638E-01	1.82660E+00	1.63026E+01	1.77765E+04	5.11962E+01
7.00368E-01	8.42483E-01	-1.28900E+00	-1.12509E+02	5.93198E+02	1.30219E+03

Damping

-1.19527E-02	5.97184E-04	3.27325E-02	2.10370E-01	-4.49657E+00	-9.70053E-01
-6.28031E-03	1.33328E-01	9.72798E-03	1.67984E+00	-8.27359E-01	2.28409E-01
2.05419E-02	2.97443E-03	1.02818E-03	-5.29079E-02	6.11895E+00	1.46270E+00
2.10370E-01	1.67984E+00	-5.29079E-02	2.14348E+01	7.67410E+01	8.15354E+00
-4.49657E+00	-8.27359E-01	6.11895E+00	1.55115E+00	-3.16157E+02	6.41150E+02
-9.70053E-01	2.28409E-01	1.46270E+00	1.53743E+01	-4.78218E+02	1.73339E+03

Frequency 2.0944 Period 3.0000

Added Mass

1.94454E-02	6.25880E-04	6.97859E-04	1.07985E-03	7.64035E+00	1.69031E-01
9.26932E-04	1.63048E-01	-6.52289E-03	1.22370E+00	5.91528E-01	8.46363E-01
3.02916E-03	-2.24240E-03	1.92523E+00	3.88079E-04	-1.39629E+00	-1.07918E+00
1.07985E-03	1.22370E+00	3.88079E-04	2.35313E+02	-3.02060E+01	1.41276E+01
7.64035E+00	5.91528E-01	-1.39629E+00	1.55298E+01	1.77437E+04	-2.74372E+02
1.69031E-01	8.46363E-01	-1.07918E+00	-9.75518E+01	4.04172E+02	1.64231E+03

Damping

1.95073E-03	8.97312E-03	6.11238E-03	1.63213E-02	-4.15291E-02	-2.76914E-02
-5.92417E-04	5.48880E-02	1.38579E-03	6.43024E-01	9.61396E-01	5.30965E-01
3.31705E-03	-1.65487E-05	2.84886E-03	-1.42195E-02	1.31199E+00	1.68336E-01
1.63213E-02	6.43024E-01	-1.42195E-02	8.83980E+00	4.47978E+01	7.50271E-01
-4.15291E-02	9.61396E-01	1.31199E+00	1.15350E+01	7.73791E+01	2.02219E+02
-2.76914E-02	5.30965E-01	1.68336E-01	-8.11768E+00	-3.59034E+02	6.79728E+02

Wave Frequency Force & Moment (1st Order)

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       *************************************************************************************************************
       *                                             ***  MOSES  ***                                               *
       *                                             ----------------                          7 November, 2017    *
       *          Motion Analysis                                                                                  *
       *          MOSES Model Plot (Bow View)                                                                      *
       *                        Draft       =  15.5 Meters               Trim Angle  =    0.00 Deg.                *
       *                        Heading     =   0.00 Deg.               Linearization Based on 1/ 60               *
       *                                                                                                           *
       *************************************************************************************************************
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+++ L I N E A R Z E D   W A V E   F R E Q U E N C Y   F O R C E S +++

Results are in Body System

Of Point On Body FLNG At X = 191.3 Y =   -0.0 Z =   24.4

Process is DEFAULT: Units Are Degrees, Meters, and M-Tons Unless Specified

E N C O U N T E R		Surge Force / Wave Ampl.		Sway Force / Wave Ampl.		Heave Force / Wave Ampl.		Roll Moment / Wave Ampl.		Pitch Moment / Wave Ampl.		Yaw Moment / Wave Ampl.	
Frequency -(Rad/Sec)-	Period -(Sec)-	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase
0.2513	25.00	1411	-15	13	177	12816	86	252	25	1125410	-14	1390	179
0.2565	24.50	1367	-12	13	-174	12146	88	242	32	1095929	-11	1347	-171
0.2618	24.00	1325	-8	13	-166	11470	91	236	39	1069929	-7	1337	-161
0.2674	23.50	1287	-4	13	-157	10792	94	235	47	1048598	-2	1366	-152
0.2732	23.00	1254	0	14	-149	10123	97	239	55	1032402	1	1435	-142
0.2793	22.50	1227	4	14	-141	9472	102	250	62	1022741	6	1544	-134
0.2856	22.00	1209	9	15	-133	8855	107	267	68	1020790	12	1687	-126
0.2922	21.50	1200	15	17	-126	8293	113	288	74	1027768	17	1856	-120
0.2992	21.00	1203	21	18	-119	7816	120	319	88	1044589	23	2076	-114
0.3065	20.50	1219	27	20	-114	7460	128	359	100	1072202	28	2352	-108
0.3142	20.00	1250	33	22	-110	7265	138	397	105	1111278	34	2648	-103
0.3222	19.50	1175	41	23	-99	6456	145	401	117	1077303	41	2831	-92
0.3307	19.00	1119	50	25	-90	5739	154	424	127	1061664	50	3116	-83
0.3396	18.50	1014	59	25	-78	4865	163	427	141	1012307	58	3308	-70
0.3491	18.00	936	71	27	-66	4108	175	456	154	987082	68	3650	-59
0.3590	17.50	796	83	27	-51	3215	-173	454	170	917911	78	3827	-45
0.3696	17.00	698	100	29	-37	2493	-154	493	-173	879662	90	4235	-32
0.3808	16.50	527	118	28	-18	1678	-136	486	-152	784747	102	4375	-15
0.3927	16.00	441	148	31	0	1231	-96	547	-133	728073	117	4889	0
0.4054	15.50	308	-171	30	22	819	-50	536	-108	602359	130	4940	19
0.4189	15.00	404	-123	34	44	1207	0	629	-86	522995	150	5583	38
0.4333	14.50	531	-85	37	70	1507	33	674	-59	403555	172	5848	60
0.4488	14.00	684	-55	39	98	1754	63	713	-30	282898	-159	5988	86
0.4654	13.50	813	-28	42	128	1865	91	748	3	182030	-116	6034	116
0.4833	13.00	880	0	45	161	1792	120	795	41	143810	-50	6132	151
0.5027	12.50	859	31	47	-161	1511	154	872	85	174640	10	6476	-166
0.5236	12.00	741	70	47	-121	1067	-161	977	133	211498	58	7135	-121
0.5464	11.50	549	122	44	-71	671	-92	1087	-174	216921	104	7987	-72
0.5712	11.00	418	-155	42	-8	672	2	1173	-115	178019	155	8730	-20
0.5984	10.50	588	-68	44	57	836	79	1266	-48	115002	-129	8431	43
0.6283	10.00	755	6	50	153	780	150	1136	30	107715	-12	8659	108
0.6614	9.50	603	91	48	-142	620	-105	1541	129	127200	87	8081	-147
0.6981	9.00	475	-146	39	-2	751	30	1474	-130	105783	-173	9974	-50
0.7392	8.50	745	-10	41	87	704	155	1938	0	112853	-21	8005	68
0.7854	8.00	620	141	38	-123	745	-43	1964	153	111085	134	7944	-135
0.8378	7.50	782	-31	31	112	718	147	1616	-33	113960	-39	6552	38
0.8976	7.00	580	-168	17	-46	788	7	1382	-165	74699	-175	5309	-91
0.9666	6.50	609	130	8	-106	812	-90	1764	87	83713	143	2791	140
1.0472	6.00	750	98	25	-5	467	-109	2140	161	90785	108	4593	-150
1.1424	5.50	418	-177	16	-14	379	22	3116	-109	37158	173	6552	-40
1.2566	5.00	526	76	28	-153	273	-160	2606	139	58029	72	10145	-164
1.3963	4.50	108	176	103	-30	124	-168	1823	-125	11050	83	14666	-50
1.5708	4.00	679	15	165	-36	834	-129	7796	-111	115318	19	54153	-84
2.0944	3.00	162	-87	310	-137	192	150	5260	-159	31144	-50	16912	-142

```
*****************************************************************************************************
*                                          ***  MOSES  ***                                          *
*                                          ---------------                       7 November, 2017   *
*         Motion Analysis                                                                           *
*         MOSES Model Plot (Bow View)                                                               *
*                     Draft       =  15.5 Meters           Trim Angle  =    0.00 Deg.               *
*                     Heading     =  45.00 Deg.            Linearization Based on 1/ 60             *
*                                                                                                   *
*****************************************************************************************************
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+++ L I N E A R Z E D   W A V E   F R E Q U E N C Y   F O R C E S +++

Results are in Body System

Of Point On Body FLNG At X = 191.3 Y = -0.0 Z = 24.4

Process is DEFAULT: Units Are Degrees, Meters, and M-Tons Unless Specified

E N C O U N T E R		Surge Force / Wave Ampl.		Sway Force / Wave Ampl.		Heave Force / Wave Ampl.		Roll Moment / Wave Ampl.		Pitch Moment / Wave Ampl.		Yaw Moment / Wave Ampl.	
Frequency -(Rad/Sec)-	Period -(Sec)-	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase
0.2513	25.00	1152	-34	2535	-42	14698	66	2514	-68	862999	-35	120158	47
0.2565	24.50	1148	-31	2577	-39	14205	68	2772	-61	856204	-31	129842	51
0.2618	24.00	1147	-28	2626	-37	13718	70	3090	-55	852109	-28	140639	55
0.2674	23.50	1149	-24	2683	-34	13241	73	3458	-50	851120	-24	152504	59
0.2732	23.00	1156	-21	2748	-32	12780	76	3871	-46	853674	-21	165407	62
0.2793	22.50	1168	-17	2822	-29	12343	80	4329	-43	860274	-17	179323	64
0.2856	22.00	1186	-13	2907	-27	11942	84	4829	-41	871516	-13	194241	67
0.2922	21.50	1211	-10	3004	-25	11585	89	5346	-39	887920	-9	210235	69
0.2992	21.00	1241	-6	3109	-22	11289	94	5900	-36	908736	-5	227593	71
0.3065	20.50	1277	-2	3220	-20	11069	99	6510	-32	934085	-1	246201	73
0.3142	20.00	1321	1	3342	-18	10943	105	7178	-29	965474	2	265872	74
0.3222	19.50	1320	6	3377	-14	10364	110	7898	-23	963441	8	288658	79
0.3307	19.00	1331	12	3429	-10	9860	116	8727	-19	972674	14	314150	82
0.3396	18.50	1320	18	3423	-6	9189	122	9528	-13	966354	21	340353	87
0.3491	18.00	1326	25	3436	-2	8606	129	10473	-8	975507	29	370322	92
0.3590	17.50	1297	33	3365	1	7832	136	11286	-2	963476	37	398916	97
0.3696	17.00	1292	41	3312	6	7163	145	12283	3	972616	46	432707	102
0.3808	16.50	1235	49	3144	11	6287	153	12959	10	951469	56	460428	108
0.3927	16.00	1206	59	2994	17	5537	165	13869	17	958218	66	495211	114
0.4054	15.50	1101	68	2697	23	4582	174	14135	25	919192	77	514726	121
0.4189	15.00	1027	80	2410	30	3774	-170	14677	34	914939	89	543644	128
0.4333	14.50	885	93	2000	37	2863	-155	14509	43	872457	101	555194	136
0.4488	14.00	702	108	1509	43	1953	-136	13752	54	809573	115	553145	145
0.4654	13.50	482	129	953	45	1083	-108	12213	66	722766	131	533284	156
0.4833	13.00	254	168	422	24	509	-36	9702	78	611700	148	491548	167
0.5027	12.50	219	-98	527	-49	897	44	6097	92	480319	169	424492	-179
0.5236	12.00	450	-45	1067	-55	1450	79	1483	94	335808	-164	330297	-165
0.5464	11.50	706	-13	1526	-43	1773	108	4039	-41	187563	-129	211156	-151
0.5712	11.00	895	14	1773	-25	1796	140	9546	-23	86789	-48	80045	-148
0.5984	10.50	974	45	1723	-2	1477	180	14065	1	146792	42	75894	114
0.6283	10.00	872	86	1346	24	953	-128	16328	31	217958	95	181165	127
0.6614	9.50	529	151	675	53	645	-36	14473	68	207082	151	229847	159
0.6981	9.00	381	-99	198	-26	882	67	7312	113	137275	-140	204256	-159
0.7392	8.50	706	-1	759	-11	851	156	3748	-24	106161	-25	96706	-113
0.7854	8.00	717	96	791	44	653	-100	12485	44	114299	102	51427	153
0.8378	7.50	481	-150	168	92	549	61	9922	120	87147	-149	120500	-145
0.8976	7.00	492	51	463	43	476	-168	3534	20	67235	77	37704	-71
0.9666	6.50	785	-83	126	120	781	-66	10864	121	144996	-78	57028	-115
1.0472	6.00	802	105	266	121	442	159	5943	107	98326	119	18973	-117
1.1424	5.50	193	45	108	107	305	-171	2085	-16	20622	-74	12774	-62
1.2566	5.00	152	137	63	-104	208	-121	3374	-61	11572	66	22874	30
1.3963	4.50	410	-2	170	-54	1152	-167	4914	-142	35876	-57	25810	-89
1.5708	4.00	345	108	173	24	417	-44	4878	-30	64559	83	22150	-10
2.0944	3.00	114	60	404	72	86	153	3730	98	20842	45	90465	-9

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 *****************************************************************************************************
 *                                         ***  MOSES  ***                                            *
 *                                         ---------------                        7 November, 2017    *
 *          Motion Analysis                                                                           *
 *          MOSES Model Plot (Bow View)                                                               *
 *                       Draft      =  15.5 Meters             Trim Angle  =   0.00 Deg.              *
 *                       Heading    =  90.00 Deg.              Linearization Based on 1/ 60           *
 *                                                                                                    *
 *****************************************************************************************************
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+++ L I N E A R Z E D   W A V E   F R E Q U E N C Y   F O R C E S +++

Results are in Body System

Of Point On Body FLNG At X = 191.3 Y = -0.0 Z = 24.4

Process is DEFAULT: Units Are Degrees, Meters, and M-Tons Unless Specified

E N C O U N T E R		Surge Force / Wave Ampl.		Sway Force / Wave Ampl.		Heave Force / Wave Ampl.		Roll Moment / Wave Ampl.		Pitch Moment / Wave Ampl.		Yaw Moment / Wave Ampl.	
Frequency -(Rad/Sec)-	Period -(Sec)-	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase
0.2513	25.00	83	-7	4006	-92	16872	16	2314	-124	18661	-35	4892	-78
0.2565	24.50	83	-8	4183	-92	16756	17	2786	-123	18903	-37	5187	-79
0.2618	24.00	84	-9	4369	-93	16638	18	3288	-122	19188	-39	5490	-79
0.2674	23.50	85	-10	4563	-93	16521	19	3812	-122	19524	-42	5800	-80
0.2732	23.00	85	-10	4767	-94	16407	20	4414	-124	19909	-44	6119	-81
0.2793	22.50	86	-11	4983	-94	16292	21	4928	-126	20374	-46	6416	-82
0.2856	22.00	87	-11	5210	-95	16178	22	5523	-129	20892	-49	6730	-83
0.2922	21.50	88	-12	5447	-95	16061	23	6164	-131	21461	-51	7076	-84
0.2992	21.00	89	-12	5692	-96	15939	24	6857	-131	22066	-53	7482	-84
0.3065	20.50	89	-14	5943	-96	15809	25	7576	-128	22697	-56	7958	-84
0.3142	20.00	90	-15	6203	-96	15675	27	8342	-124	23370	-58	8486	-84
0.3222	19.50	90	-16	6479	-97	15534	28	9425	-119	23209	-61	9129	-84
0.3307	19.00	89	-18	6770	-97	15390	29	10526	-115	23112	-64	9784	-85
0.3396	18.50	88	-19	7065	-98	15223	30	11841	-113	22550	-67	10443	-86
0.3491	18.00	87	-20	7379	-98	15057	31	13245	-112	22022	-70	11130	-87
0.3590	17.50	86	-20	7680	-99	14844	32	14865	-112	21037	-72	11769	-89
0.3696	17.00	85	-20	8002	-100	14627	33	16590	-111	20026	-74	12455	-91
0.3808	16.50	84	-19	8293	-101	14341	35	18504	-112	18803	-73	12996	-94
0.3927	16.00	83	-18	8604	-102	14048	36	20551	-112	17516	-73	13596	-96
0.4054	15.50	83	-16	8863	-102	13683	38	22739	-113	16584	-69	13933	-99
0.4189	15.00	84	-14	9141	-103	13308	39	25081	-113	15684	-65	14323	-101
0.4333	14.50	87	-12	9374	-104	12890	42	27529	-114	15561	-58	14469	-104
0.4488	14.00	91	-12	9577	-104	12454	44	30088	-114	16152	-52	14454	-106
0.4654	13.50	95	-12	9747	-105	12012	47	32755	-114	17422	-47	14289	-107
0.4833	13.00	97	-15	9873	-104	11573	50	35515	-114	19024	-44	14024	-108
0.5027	12.50	95	-18	9942	-104	11130	54	38316	-113	20277	-44	13792	-107
0.5236	12.00	87	-20	9934	-103	10650	57	41022	-112	20414	-45	13645	-106
0.5464	11.50	76	-18	9838	-102	10083	61	43431	-110	19367	-43	13423	-105
0.5712	11.00	69	-10	9659	-100	9447	65	45393	-107	17591	-31	12681	-104
0.5984	10.50	44	-15	9423	-96	8724	71	47027	-103	13288	-29	11188	-101
0.6283	10.00	48	-52	9136	-92	7849	77	48488	-97	14966	-51	10503	-102
0.6614	9.50	63	-46	8827	-86	6970	83	50348	-90	21318	-45	9086	-87
0.6981	9.00	28	0	8454	-79	6247	91	51592	-82	15883	-12	8879	-77
0.7392	8.50	3	-109	8023	-69	5297	103	52509	-71	11583	-27	6510	-58
0.7854	8.00	20	35	7587	-58	4283	115	53178	-58	18564	-13	5644	-38
0.8378	7.50	39	-63	7130	-43	3601	137	54230	-42	24504	-54	5132	19
0.8976	7.00	109	110	6594	-26	2704	134	55655	-25	33576	53	10931	9
0.9666	6.50	348	100	5796	-5	2387	163	53374	-5	68938	91	9150	6
1.0472	6.00	236	109	6497	40	1619	-159	64180	38	31171	81	10671	89
1.1424	5.50	77	89	4907	67	498	-126	51726	68	11586	35	3723	96
1.2566	5.00	143	-77	4023	114	2136	-86	47751	114	25473	-112	7668	-164
1.3963	4.50	126	4	796	-110	106	-56	4068	142	28563	-18	17387	-85
1.5708	4.00	178	29	2686	-74	1244	167	33701	-77	45105	25	23768	-65
2.0944	3.00	66	-166	1411	-75	89	-100	15500	-74	16782	18	12126	-42

*** MOSES ***

7 November, 2017

Motion Analysis

MOSES Model Plot (Bow View)

Draft = 15.5 Meters Trim Angle = 0.00 Deg.

Heading = 135.00 Deg. Linearization Based on 1/ 60

+++ L I N E A R Z E D W A V E F R E Q U E N C Y F O R C E S +++

Results are in Body System

Of Point On Body FLNG At X = 191.3 Y = -0.0 Z = 24.4

Process is DEFAULT: Units Are Degrees, Meters, and M-Tons Unless Specified

E N C O U N T E R		Surge Force / Wave Ampl.		Sway Force / Wave Ampl.		Heave Force / Wave Ampl.		Roll Moment / Wave Ampl.		Pitch Moment / Wave Ampl.		Yaw Moment / Wave Ampl.	
Frequency -(Rad/Sec)-	Period -(Sec)-	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase
0.2513	25.00	1158	43	2556	-142	14957	-33	1876	-171	860545	45	120605	129
0.2565	24.50	1170	42	2584	-145	14604	-34	2241	-174	867607	43	130435	124
0.2618	24.00	1183	40	2622	-149	14242	-35	2622	-177	875637	42	141493	120
0.2674	23.50	1198	39	2671	-152	13873	-36	3017	-179	884761	40	153706	116
0.2732	23.00	1214	37	2731	-155	13496	-38	3429	179	895122	39	167020	113
0.2793	22.50	1232	35	2803	-159	13113	-39	3853	177	906951	37	181387	110
0.2856	22.00	1253	34	2890	-162	12726	-41	4290	175	920371	35	196795	107
0.2922	21.50	1275	32	2991	-166	12336	-43	4732	173	935371	33	213231	105
0.2992	21.00	1299	31	3102	-169	11941	-45	5174	173	951538	32	230716	103
0.3065	20.50	1324	29	3223	-172	11541	-47	5632	174	969120	30	249275	101
0.3142	20.00	1353	27	3359	-175	11142	-50	6095	175	989171	28	268920	100
0.3222	19.50	1365	25	3386	180	10585	-53	6787	171	997661	26	292189	95
0.3307	19.00	1379	23	3442	175	10024	-56	7530	168	1008632	23	318499	90
0.3396	18.50	1384	20	3424	169	9381	-59	8309	163	1015289	21	345057	85
0.3491	18.00	1393	18	3443	163	8731	-62	9191	159	1025029	18	376237	79
0.3590	17.50	1385	15	3351	156	7994	-65	9976	153	1027294	15	404696	72
0.3696	17.00	1381	11	3308	149	7244	-69	10908	148	1033440	12	440388	66
0.3808	16.50	1347	8	3111	141	6413	-73	11615	141	1026510	8	466537	58
0.3927	16.00	1317	3	2975	132	5561	-78	12526	134	1024760	3	504134	50
0.4054	15.50	1238	0	2636	123	4652	-81	12891	126	998107	-1	519241	39
0.4189	15.00	1163	-5	2372	110	3706	-87	13575	118	978744	-7	552038	30
0.4333	14.50	1037	-10	1951	97	2730	-91	13646	108	932103	-14	562198	18
0.4488	14.00	875	-15	1448	81	1749	-93	13215	98	863853	-22	557930	5
0.4654	13.50	678	-17	885	57	844	-80	12086	86	770468	-30	535246	-8
0.4833	13.00	461	-12	391	0	612	-10	10051	73	650288	-39	490516	-24
0.5027	12.50	306	16	611	-96	1264	13	6968	60	504303	-49	420551	-42
0.5236	12.00	423	55	1145	-133	1851	8	2897	51	337683	-58	323011	-62
0.5464	11.50	709	60	1574	-159	2161	-2	2173	-179	164924	-58	199473	-88
0.5712	11.00	952	49	1789	175	2134	-16	7325	174	92183	6	66949	-138
0.5984	10.50	1111	30	1707	148	1694	-29	12121	153	207499	26	92048	79
0.6283	10.00	1114	13	1296	117	955	-31	15525	127	298520	13	189289	37
0.6614	9.50	779	3	578	81	744	14	15202	101	279150	-1	233533	3
0.6981	9.00	403	25	249	-96	1330	27	9925	71	159925	-10	199564	-34
0.7392	8.50	698	55	818	-160	1232	13	2238	120	122665	36	84260	-81
0.7854	8.00	833	45	767	146	635	13	11357	145	184880	42	63663	66
0.8378	7.50	461	13	92	30	869	62	12571	95	116781	9	122297	0
0.8976	7.00	560	88	533	-154	794	17	2248	124	120334	84	23726	-83
0.9666	6.50	199	71	60	70	348	108	13670	110	20177	93	73462	28
1.0472	6.00	934	22	287	-169	520	40	6460	144	171480	28	30963	99
1.1424	5.50	210	101	218	-160	477	6	3890	39	66195	67	13488	123
1.2566	5.00	651	61	131	-92	562	169	7139	-169	93668	70	15132	-99
1.3963	4.50	755	178	109	73	850	-6	2402	24	68983	162	33511	91
1.5708	4.00	707	38	270	5	923	-125	7059	-115	100765	24	61090	-77
2.0944	3.00	138	86	738	-7	181	-108	8220	-20	34098	11	68572	102

*** MOSES ***

7 November, 2017

Motion Analysis

MOSES Model Plot (Bow View)

Draft = 15.5 Meters Trim Angle = 0.00 Deg.

Heading = 180.00 Deg. Linearization Based on 1/ 60

+++ L I N E A R Z E D W A V E F R E Q U E N C Y F O R C E S +++

Results are in Body System

Of Point On Body FLNG At X = 191.3 Y = -0.0 Z = 24.4

Process is DEFAULT: Units Are Degrees, Meters, and M-Tons Unless Specified

E N C O U N T E R		Surge Force / Wave Ampl.		Sway Force / Wave Ampl.		Heave Force / Wave Ampl.		Roll Moment / Wave Ampl.		Pitch Moment / Wave Ampl.		Yaw Moment / Wave Ampl.	
Frequency -(Rad/Sec)-	Period -(Sec)-	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase
0.2513	25.00	1457	25	10	160	13044	-54	278	-11	1143399	25	993	167
0.2565	24.50	1438	23	10	152	12515	-55	266	-16	1133327	23	921	158
0.2618	24.00	1419	21	9	143	11971	-56	257	-23	1125045	20	872	148
0.2674	23.50	1402	19	8	132	11412	-58	249	-30	1118873	18	853	137
0.2732	23.00	1387	17	8	120	10839	-60	246	-37	1115168	15	868	125
0.2793	22.50	1374	14	9	107	10253	-62	247	-46	1114322	12	918	114
0.2856	22.00	1363	12	9	95	9656	-64	258	-56	1116769	9	996	105
0.2922	21.50	1356	9	11	86	9052	-67	289	-60	1123052	6	1080	98
0.2992	21.00	1352	6	12	79	8449	-71	333	-58	1133506	3	1181	91
0.3065	20.50	1352	3	13	73	7857	-76	344	-61	1148654	0	1360	84
0.3142	20.00	1358	0	15	67	7289	-81	352	-69	1169261	-3	1568	79
0.3222	19.50	1301	-1	15	53	6504	-84	334	-81	1145618	-7	1623	63
0.3307	19.00	1245	-4	16	39	5696	-88	335	-94	1126976	-11	1785	49
0.3396	18.50	1163	-7	15	23	4866	-91	321	-108	1087679	-16	1816	31
0.3491	18.00	1080	-10	16	7	3998	-94	327	-123	1053701	-21	2023	15
0.3590	17.50	971	-11	15	-10	3191	-94	313	-141	993150	-26	2010	-6
0.3696	17.00	855	-12	17	-29	2331	-95	328	-159	937728	-32	2284	-26
0.3808	16.50	738	-9	15	-50	1710	-86	313	178	850308	-38	2184	-52
0.3927	16.00	613	-4	17	-72	1149	-66	344	156	766239	-45	2540	-76
0.4054	15.50	570	7	15	-97	1198	-41	328	130	651268	-50	2282	-106
0.4189	15.00	557	23	17	-123	1477	-20	379	104	533907	-58	2713	-135
0.4333	14.50	666	33	17	-153	1849	-18	399	76	401355	-63	2726	-168
0.4488	14.00	822	36	17	172	2110	-22	414	46	272017	-61	2668	155
0.4654	13.50	976	32	18	132	2184	-29	422	14	178567	-44	2544	116
0.4833	13.00	1087	25	18	87	2027	-37	420	-21	178045	-13	2394	75
0.5027	12.50	1116	15	18	36	1637	-44	412	-64	239260	-2	2308	29
0.5236	12.00	1026	6	16	-20	1117	-42	411	-116	286069	-7	2378	-23
0.5464	11.50	812	1	14	-80	843	-15	437	180	280894	-18	2599	-87
0.5712	11.00	612	15	11	-141	1130	3	455	109	212532	-26	2589	-163
0.5984	10.50	760	32	13	125	1352	0	549	31	138233	-12	2709	106
0.6283	10.00	1053	25	13	86	1094	-10	443	-36	183494	13	2564	15
0.6614	9.50	940	11	12	-84	837	6	531	-157	218873	6	2400	-96
0.6981	9.00	599	18	4	-101	1266	17	497	90	146090	-1	2383	148
0.7392	8.50	943	25	9	22	1019	3	746	-34	175966	21	2616	-3
0.7854	8.00	715	12	12	-167	1026	21	813	146	171982	7	3441	-170
0.8378	7.50	820	21	2	124	989	9	728	-42	156192	21	3340	-18
0.8976	7.00	458	20	6	-58	1063	16	722	90	101552	6	1582	114
0.9666	6.50	712	15	8	135	960	5	1988	144	160720	5	5813	172
1.0472	6.00	816	16	5	-24	868	7	874	148	168851	10	3293	-168
1.1424	5.50	371	-7	14	122	829	19	1632	47	83099	-6	4604	110
1.2566	5.00	620	12	24	-132	298	15	1904	146	117412	10	7786	-149
1.3963	4.50	108	3	82	127	710	5	1639	25	38544	-3	11639	108
1.5708	4.00	1050	56	181	0	975	-72	8726	-76	169949	49	59169	-49
2.0944	3.00	232	107	461	-16	208	-68	7979	-39	61374	79	22757	-23

Mean Drift Force & Moment (2nd Order)

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         *******************************************************************************************************
         *                                              ***  MOSES  ***                                        *
         *                                              ---------------                    7 November, 2017    *
         *          Motion Analysis                                                                            *
         *          MOSES Model Plot (Bow View)                                                                *
         *                                                                                                     *
         *******************************************************************************************************

                         +++ M E A N   D R I F T   F O R C E S   F O R   F L N G +++
                         ===========================================================

                              Drift Name = FLNG      Heading = 0.00    Computed

               Force Factor =   1.0000   Radiation Factor =   1.0000   Coriolis Factor =   1.00

                  Process is DEFAULT: Units Are Degrees, Meters, and M-Tons Unless Specified

                       Mean Drift Force ( With No Force Factor ) / (Wave Amplitude)**2

                                         Reported in the Body System
```

E N C O U N T E R		T R A N S L A T I O N			R O T A T I O N		
Frequency	Period	Surge	Sway	Heave	Roll	Pitch	Yaw
0.2513	25.000	73.7	-0.2	-64.3	6.7	15584.7	-1295.4
0.3142	20.000	102.9	-0.6	-83.5	20.2	20655.1	-1851.5
0.3307	19.000	109.5	-0.4	-87.3	19.9	21719.3	-1893.2
0.3491	18.000	112.9	-0.0	-90.9	18.7	22766.6	-1838.2
0.3696	17.000	113.1	-0.6	-94.0	13.0	23675.6	-1992.5
0.3927	16.000	115.8	-0.2	-98.0	17.8	24998.8	-1947.6
0.4189	15.000	125.0	-0.7	-101.9	32.6	26468.4	-2151.4
0.4333	14.500	129.1	-0.7	-103.2	42.1	27011.7	-2223.5
0.4488	14.000	130.2	-0.8	-104.0	51.1	27383.9	-2260.3
0.4654	13.500	128.8	-1.0	-104.8	61.0	27772.0	-2272.2
0.4833	13.000	129.3	-1.2	-105.7	74.2	28243.6	-2321.9
0.5027	12.500	134.2	-1.4	-106.7	93.5	28852.1	-2444.7
0.5236	12.000	137.4	-1.2	-106.6	107.3	29112.0	-2392.9
0.5464	11.500	135.0	-0.8	-105.9	120.5	29090.2	-2202.9
0.5712	11.000	134.4	-1.6	-105.0	151.5	29116.4	-2413.0
0.5984	10.500	134.7	-1.3	-104.3	181.3	28998.2	-2384.1
0.6283	10.000	133.3	-0.4	-101.6	194.4	28496.9	-2070.6
0.6614	9.500	132.0	-1.2	-99.1	241.4	27898.1	-2259.7
0.6981	9.000	125.7	1.9	-93.5	193.4	26496.5	-1121.7
0.7392	8.500	112.1	2.6	-91.7	231.4	25833.3	-688.9
0.7854	8.000	88.5	2.3	-84.9	270.7	23989.3	-506.9
0.8378	7.500	49.8	1.3	-75.1	286.0	20946.8	-482.6
0.8976	7.000	7.8	1.0	-70.7	249.3	17795.0	-203.4
0.9666	6.500	18.9	-2.7	-92.6	193.6	20944.3	-1200.7
1.0472	6.000	-4.8	9.0	-64.9	23.2	19283.1	2800.3
1.1424	5.500	-30.4	-2.0	-49.1	110.6	13538.9	-344.4
1.2566	5.000	-96.4	2.7	-47.6	-104.2	12825.0	-910.2
1.3963	4.500	-143.7	-30.5	-45.2	538.0	9987.2	-3205.7
1.5708	4.000	-2020.2	54.3	-73.4	-222.5	-10699.6	53534.5
2.0944	3.000	-408.2	158.7	-12.4	-2267.1	-3542.6	34552.2

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*******************************************************************************************************************
*                                                  ***  MOSES  ***                                                  *
*                                                  ---------------                           7 November, 2017     *
*        Motion Analysis                                                                                            *
*        MOSES Model Plot (Bow View)                                                                                *
*                                                                                                                   *
*******************************************************************************************************************
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+++ M E A N   D R I F T   F O R C E S   F O R   F L N G +++

Drift Name = FLNG   Heading = 45.00   Computed

Force Factor =   1.0000   Radiation Factor =   1.0000   Coriolis Factor =   1.00

Process is DEFAULT: Units Are Degrees, Meters, and M-Tons Unless Specified

Mean Drift Force (With No Force Factor) / (Wave Amplitude)**2

Reported in the Body System

E N C O U N T E R		T R A N S L A T I O N			R O T A T I O N		
Frequency	Period	Surge	Sway	Heave	Roll	Pitch	Yaw
0.2513	25.000	39.4	11.1	-110.1	-289.9	24251.6	1674.1
0.3142	20.000	46.8	19.2	-160.0	-731.2	34357.0	3361.8
0.3307	19.000	51.4	20.1	-171.4	-823.7	36534.9	3510.0
0.3491	18.000	56.7	21.7	-184.2	-959.9	38953.9	3833.9
0.3696	17.000	60.2	23.1	-196.4	-1093.2	41175.5	4243.9
0.3927	16.000	59.4	26.3	-210.0	-1299.0	43494.3	5224.1
0.4189	15.000	56.3	20.6	-216.3	-1302.9	44046.2	4181.8
0.4333	14.500	56.9	18.6	-220.0	-1328.3	44842.7	4248.6
0.4488	14.000	60.4	11.4	-224.2	-1350.0	45693.9	2820.6
0.4654	13.500	64.9	4.8	-228.7	-1380.5	46481.3	1449.9
0.4833	13.000	66.6	2.2	-232.4	-1410.7	47393.0	1496.2
0.5027	12.500	63.2	-3.9	-232.1	-1305.6	47554.9	910.6
0.5236	12.000	59.3	-10.2	-231.0	-1254.2	47369.2	186.5
0.5464	11.500	62.3	-21.0	-228.5	-1130.9	47033.3	-1564.0
0.5712	11.000	65.1	-28.4	-227.5	-1023.1	47381.7	-2528.3
0.5984	10.500	63.4	-38.6	-225.1	-908.6	47384.3	-4374.0
0.6283	10.000	66.1	-60.1	-213.2	-478.3	45330.0	-8590.6
0.6614	9.500	59.7	-79.6	-202.7	-99.4	43677.6	-12605.6
0.6981	9.000	52.3	-96.2	-188.3	308.5	41882.6	-15760.4
0.7392	8.500	35.3	-122.2	-171.5	809.1	39287.5	-21186.1
0.7854	8.000	20.9	-144.7	-155.2	1228.5	36199.2	-26180.4
0.8378	7.500	14.2	-174.5	-139.4	1732.2	33385.8	-32431.5
0.8976	7.000	26.3	-204.5	-140.8	2127.5	33004.7	-38637.0
0.9666	6.500	197.1	-244.3	-511.2	3141.9	110517.0	-43121.2
1.0472	6.000	44.0	-182.6	-151.9	2630.2	23842.0	-32671.0
1.1424	5.500	-2.4	-156.7	-108.1	2448.1	20236.6	-27805.7
1.2566	5.000	-51.7	-221.1	-63.6	3105.5	11858.7	-36197.1
1.3963	4.500	-1059.8	-307.5	-124.1	4603.1	15681.3	-48397.3
1.5708	4.000	-519.6	-150.7	-45.1	1934.6	5028.2	-10837.9
2.0944	3.000	-190.4	-177.5	-14.0	2425.4	361.1	-44831.5

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****************************************************************************************************
*                                        ***  MOSES  ***                                           *
*                                        ---------------                          7 November, 2017 *
*         Motion Analysis                                                                          *
*         MOSES Model Plot (Bow View)                                                              *
*                                                                                                  *
****************************************************************************************************
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+++ M E A N   D R I F T   F O R C E S   F O R   F L N G +++

Drift Name = FLNG   Heading = 90.00   Computed

Force Factor =   1.0000   Radiation Factor =   1.0000   Coriolis Factor =   1.00

Process is DEFAULT: Units Are Degrees, Meters, and M-Tons Unless Specified

Mean Drift Force (With No Force Factor) / (Wave Amplitude)**2

Reported in the Body System

E N C O U N T E R		T R A N S L A T I O N			R O T A T I O N		
Frequency	Period	Surge	Sway	Heave	Roll	Pitch	Yaw
0.2513	25.000	5.2	-12.5	-122.3	183.8	26335.9	-1710.7
0.3142	20.000	5.9	-27.6	-188.2	288.7	40333.0	-3222.3
0.3307	19.000	5.8	-43.5	-199.1	396.5	42758.1	-5982.0
0.3491	18.000	5.8	-59.4	-209.2	511.6	45013.7	-8720.3
0.3696	17.000	5.6	-72.0	-218.6	576.0	47193.7	-10728.6
0.3927	16.000	5.3	-86.6	-223.1	689.7	48229.1	-13524.5
0.4189	15.000	5.1	-101.6	-222.2	831.0	48274.9	-16195.6
0.4333	14.500	4.9	-109.6	-219.3	911.1	47778.8	-17571.1
0.4488	14.000	4.6	-119.4	-214.5	1011.4	47002.1	-19059.5
0.4654	13.500	4.0	-128.5	-208.7	1106.2	45959.1	-20539.9
0.4833	13.000	3.1	-138.3	-201.5	1221.8	44695.4	-22190.7
0.5027	12.500	2.0	-147.6	-192.7	1322.3	43078.9	-23595.5
0.5236	12.000	1.0	-152.7	-190.0	1180.6	42696.4	-24176.2
0.5464	11.500	2.6	-158.5	-184.0	1101.7	41854.8	-25104.8
0.5712	11.000	2.2	-164.1	-180.0	940.9	41673.4	-26068.5
0.5984	10.500	0.2	-175.8	-168.0	1088.2	38786.8	-28748.2
0.6283	10.000	-3.8	-188.1	-156.5	1330.6	36430.1	-31625.9
0.6614	9.500	-6.0	-201.3	-145.6	1588.4	34472.1	-34959.8
0.6981	9.000	-3.9	-212.8	-129.1	1823.8	30657.9	-37960.3
0.7392	8.500	-6.8	-221.5	-124.8	1950.5	29875.4	-40205.2
0.7854	8.000	-11.5	-221.0	-121.5	1969.8	29296.8	-40517.5
0.8378	7.500	-31.9	-203.2	-171.5	1677.4	39689.8	-37821.1
0.8976	7.000	-28.1	-278.5	-158.6	3421.4	30452.3	-51986.5
0.9666	6.500	-114.0	-264.3	-140.0	3376.3	26574.9	-49213.1
1.0472	6.000	-71.3	-344.7	-220.4	5073.4	43455.9	-64998.1
1.1424	5.500	-43.5	-279.7	-51.9	3771.4	11027.7	-52706.5
1.2566	5.000	7.6	-366.3	-51.6	5083.7	11839.9	-72019.0
1.3963	4.500	-84.9	-31.0	-35.8	392.2	8438.5	-5707.6
1.5708	4.000	-467.1	-100.0	-42.9	1177.6	6221.1	-10206.5
2.0944	3.000	-39.5	-155.5	-3.9	2187.9	382.2	-30758.9

*** MOSES ***

7 November, 2017

Motion Analysis
MOSES Model Plot (Bow View)

+++ M E A N D R I F T F O R C E S F O R F L N G +++

Drift Name = FLNG Heading = 135.00 Computed

Force Factor = 1.0000 Radiation Factor = 1.0000 Coriolis Factor = 1.00

Process is DEFAULT: Units Are Degrees, Meters, and M-Tons Unless Specified

Mean Drift Force (With No Force Factor) / (Wave Amplitude)**2

Reported in the Body System

E N C O U N T E R		T R A N S L A T I O N			R O T A T I O N		
Frequency	Period	Surge	Sway	Heave	Roll	Pitch	Yaw
0.2513	25.000	70.8	2.1	-108.5	-376.7	24153.4	157.7
0.3142	20.000	91.8	10.6	-155.0	-822.1	34235.6	2409.9
0.3307	19.000	97.7	14.2	-166.5	-954.7	36851.8	3420.2
0.3491	18.000	104.7	18.8	-180.1	-1150.5	40120.5	4855.8
0.3696	17.000	112.9	14.6	-189.2	-1203.5	41985.4	3713.3
0.3927	16.000	122.6	13.2	-199.1	-1292.4	44223.9	3266.0
0.4189	15.000	133.0	17.2	-212.7	-1544.1	47550.2	4255.6
0.4333	14.500	138.3	15.5	-217.3	-1606.3	48883.4	4040.4
0.4488	14.000	143.7	15.6	-223.8	-1734.0	50638.8	4231.4
0.4654	13.500	149.1	12.6	-227.5	-1774.9	51835.7	3818.1
0.4833	13.000	154.0	8.4	-228.7	-1746.3	52395.0	3034.5
0.5027	12.500	157.7	-0.1	-226.1	-1609.1	52293.2	1504.4
0.5236	12.000	159.6	-2.5	-228.2	-1642.2	52936.1	853.7
0.5464	11.500	159.0	-11.5	-226.3	-1543.8	52676.6	-1133.6
0.5712	11.000	160.4	-19.2	-228.0	-1545.1	53244.3	-2863.8
0.5984	10.500	170.0	-33.2	-222.3	-1307.3	51923.4	-6174.2
0.6283	10.000	136.2	-48.3	-218.1	-1187.0	50402.8	-9150.0
0.6614	9.500	136.7	-62.1	-211.6	-954.6	49214.6	-11562.9
0.6981	9.000	107.7	-91.6	-187.2	-284.0	42578.7	-17002.6
0.7392	8.500	111.1	-121.6	-166.6	375.1	37676.0	-22772.9
0.7854	8.000	84.9	-142.9	-151.2	863.4	33845.7	-25455.4
0.8378	7.500	71.8	-175.1	-138.7	1411.6	31175.6	-30766.3
0.8976	7.000	73.2	-204.8	-144.5	1914.4	31203.4	-36989.8
0.9666	6.500	133.5	-230.3	-400.8	2456.8	58010.4	-44526.1
1.0472	6.000	69.6	-170.9	-124.4	2105.3	32198.3	-36209.8
1.1424	5.500	18.5	-133.4	-116.6	1080.8	35101.3	-24966.9
1.2566	5.000	-119.7	-91.4	-129.7	-439.1	41500.7	-9672.0
1.3963	4.500	-623.2	-324.9	-97.7	4315.8	21382.2	-38570.2
1.5708	4.000	-1967.3	-50.1	-58.5	773.7	-11446.9	26242.0
2.0944	3.000	-577.9	-278.5	-14.1	3485.0	-959.6	-48532.0

*** MOSES ***

7 November, 2017

Motion Analysis

MOSES Model Plot (Bow View)

+++ M E A N D R I F T F O R C E S F O R F L N G +++

Drift Name = FLNG Heading = 180.00 Computed

Force Factor = 1.0000 Radiation Factor = 1.0000 Coriolis Factor = 1.00

Process is DEFAULT: Units Are Degrees, Meters, and M-Tons Unless Specified

Mean Drift Force (With No Force Factor) / (Wave Amplitude)**2

Reported in the Body System

E N C O U N T E R		T R A N S L A T I O N			R O T A T I O N		
Frequency	Period	Surge	Sway	Heave	Roll	Pitch	Yaw
0.2513	25.000	68.4	-0.4	-62.5	9.9	14144.5	-1137.3
0.3142	20.000	70.1	-0.6	-80.7	11.5	17130.3	-1180.1
0.3307	19.000	68.9	-0.9	-84.3	15.0	17672.3	-1253.7
0.3491	18.000	66.8	-0.2	-87.9	6.4	18163.0	-1015.6
0.3696	17.000	63.7	-0.8	-91.1	12.9	18527.5	-1116.4
0.3927	16.000	59.6	-1.2	-94.3	17.4	18806.1	-1158.6
0.4189	15.000	55.1	-0.1	-97.3	7.2	19029.1	-761.9
0.4333	14.500	52.9	-0.6	-98.2	12.8	19027.9	-846.9
0.4488	14.000	50.6	-0.6	-98.7	14.2	18943.5	-823.0
0.4654	13.500	48.3	-0.6	-98.9	14.5	18825.4	-781.3
0.4833	13.000	46.0	-0.6	-99.1	15.8	18683.4	-761.5
0.5027	12.500	44.0	-1.2	-99.0	21.1	18523.7	-810.1
0.5236	12.000	42.3	-1.4	-98.2	24.7	18307.7	-799.6
0.5464	11.500	40.5	-1.5	-97.0	27.8	18063.5	-817.5
0.5712	11.000	36.5	-1.4	-95.2	29.1	17646.8	-757.1
0.5984	10.500	43.6	-1.6	-94.7	52.1	18085.4	-896.0
0.6283	10.000	42.5	-1.3	-92.5	48.4	17910.7	-834.5
0.6614	9.500	41.1	-1.5	-88.6	43.9	17478.3	-839.7
0.6981	9.000	35.0	-0.7	-84.7	51.4	16957.0	-512.3
0.7392	8.500	44.7	-1.9	-81.0	90.7	17186.5	-946.9
0.7854	8.000	43.8	-1.5	-73.6	82.9	16024.7	-769.2
0.8378	7.500	40.9	-1.3	-68.4	91.1	15077.8	-595.5
0.8976	7.000	29.3	-1.8	-70.6	70.6	15012.7	-551.3
0.9666	6.500	69.5	-1.0	-78.9	7.1	19289.7	178.0
1.0472	6.000	41.0	-0.7	-40.5	22.0	7858.5	306.9
1.1424	5.500	22.2	-7.3	-29.2	52.0	7589.1	-1213.1
1.2566	5.000	-7.9	-21.3	-27.1	139.8	7505.9	-4290.1
1.3963	4.500	-45.2	-13.0	-38.0	-6.3	13108.8	-603.9
1.5708	4.000	-2657.7	-27.8	-35.9	820.0	-26085.7	23445.9
2.0944	3.000	-934.3	-326.9	-7.4	4123.2	-5344.3	-62137.4

Response Amplitude Operator (RAO)

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          ****************************************************************************************************
          *                                        ***  MOSES  ***                                           *
          *                                        ----------------                     7 November, 2017    *
          *         Motion Analysis                                                                          *
          *         MOSES Model Plot (Bow View)                                                              *
          *   Draft            =  15.5 Meters      Trim Angle       =   0.00 Deg.     GMT             =   6.3 Meters *
          *   Roll Gy. Radius  =  21.5 Meters      Pitch Gy. Radius = 124.6 Meters    Yaw Gy. Radius   = 125.5 Meters *
          *   Heading          =   0.00 Deg.       Forward Speed    =  0.00 Knots     Linearization Based on 1/ 60    *
          *                                                                                                  *
          ****************************************************************************************************

                              +++ M O T I O N   R E S P O N S E   O P E R A T O R S +++
                              =========================================================

                                              Results are in Body System

                              Of Point On Body FLNG At X =  191.3 Y =   -0.0 Z =   24.4

                      Process is DEFAULT: Units Are Degrees, Meters, and M-Tons Unless Specified
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E N C O U N T E R		Surge / Wave Ampl.		Sway / Wave Ampl.		Heave / Wave Ampl.		Roll / Wave Ampl.		Pitch / Wave Ampl.		Yaw / Wave Ampl.	
Frequency -(Rad/Sec)-	Period -(Sec)-	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase
0.2513	25.00	0.728	159	0.002	90	0.777	70	0.027	86	0.335	-20	0.001	89
0.2565	24.50	0.684	161	0.002	95	0.745	71	0.032	91	0.333	-17	0.001	95
0.2618	24.00	0.645	164	0.002	101	0.711	73	0.038	95	0.332	-14	0.002	100
0.2674	23.50	0.609	167	0.001	110	0.677	75	0.047	98	0.333	-10	0.002	105
0.2732	23.00	0.576	171	0.001	141	0.642	78	0.060	100	0.336	-7	0.002	110
0.2793	22.50	0.549	175	0.001	-143	0.608	81	0.082	99	0.342	-3	0.002	116
0.2856	22.00	0.526	179	0.003	-123	0.575	85	0.120	92	0.351	1	0.002	122
0.2922	21.50	0.507	-176	0.008	-138	0.545	90	0.179	71	0.364	5	0.002	130
0.2992	21.00	0.494	-172	0.012	-168	0.519	96	0.211	37	0.382	9	0.002	134
0.3065	20.50	0.486	-168	0.012	169	0.501	103	0.172	12	0.405	12	0.003	136
0.3142	20.00	0.482	-165	0.011	159	0.493	110	0.129	1	0.435	16	0.003	139
0.3222	19.50	0.440	-160	0.010	160	0.445	116	0.100	1	0.436	21	0.003	145
0.3307	19.00	0.404	-155	0.009	163	0.402	124	0.082	4	0.444	26	0.003	152
0.3396	18.50	0.355	-150	0.009	170	0.348	131	0.069	11	0.437	32	0.003	160
0.3491	18.00	0.314	-143	0.008	177	0.300	142	0.061	18	0.439	39	0.003	168
0.3590	17.50	0.260	-138	0.008	-172	0.242	151	0.053	28	0.421	46	0.003	177
0.3696	17.00	0.214	-131	0.008	-162	0.194	168	0.049	38	0.414	54	0.003	-173
0.3808	16.50	0.160	-127	0.007	-150	0.137	-176	0.042	50	0.379	62	0.003	-162
0.3927	16.00	0.113	-119	0.007	-136	0.102	-140	0.039	63	0.359	72	0.003	-151
0.4054	15.50	0.069	-124	0.006	-119	0.067	-99	0.032	79	0.307	82	0.003	-137
0.4189	15.00	0.032	-137	0.006	-100	0.102	-48	0.030	97	0.273	97	0.003	-120
0.4333	14.50	0.031	164	0.005	-77	0.137	-15	0.025	120	0.219	114	0.003	-100
0.4488	14.00	0.052	152	0.005	-49	0.174	8	0.021	147	0.162	137	0.002	-74
0.4654	13.50	0.068	161	0.005	-17	0.203	30	0.018	-177	0.110	172	0.002	-41
0.4833	13.00	0.071	177	0.005	20	0.212	51	0.017	-136	0.089	-131	0.002	-1
0.5027	12.50	0.060	-161	0.005	58	0.192	73	0.016	-93	0.113	-80	0.002	41
0.5236	12.00	0.037	-129	0.004	99	0.140	102	0.016	-49	0.135	-47	0.002	84
0.5464	11.50	0.014	-54	0.004	145	0.083	154	0.015	-2	0.125	-16	0.002	129
0.5712	11.00	0.023	66	0.004	-155	0.072	-123	0.013	53	0.088	19	0.002	178
0.5984	10.50	0.039	126	0.003	-90	0.076	-62	0.011	123	0.046	82	0.002	-115
0.6283	10.00	0.042	-166	0.003	3	0.057	-3	0.009	-155	0.033	-165	0.002	-49
0.6614	9.50	0.028	-81	0.003	74	0.035	91	0.010	-54	0.031	-72	0.002	54
0.6981	9.00	0.022	43	0.002	-156	0.033	-135	0.009	45	0.021	19	0.002	148
0.7392	8.50	0.032	175	0.002	-57	0.024	-16	0.009	178	0.018	171	0.001	-91
0.7854	8.00	0.023	-33	0.002	90	0.021	141	0.008	-26	0.014	-36	0.001	61
0.8378	7.50	0.027	154	0.001	-50	0.015	-31	0.007	145	0.012	149	0.001	-128
0.8976	7.00	0.018	14	0.001	155	0.014	-164	0.004	16	0.006	6	0.001	106
0.9666	6.50	0.016	-49	0.000	0	0.011	94	0.005	-85	0.005	-34	0.000	0
1.0472	6.00	0.017	-77	0.001	151	0.005	71	0.005	-16	0.005	-65	0.000	0
1.1424	5.50	0.008	3	0.001	179	0.003	-157	0.006	72	0.002	-4	0.000	0
1.2566	5.00	0.009	-101	0.001	41	0.002	20	0.004	-38	0.002	-104	0.001	21
1.3963	4.50	0.001	-2	0.001	151	0.001	12	0.002	54	0.000	0	0.001	130
1.5708	4.00	0.007	-165	0.002	151	0.003	48	0.007	68	0.002	-161	0.002	97
2.0944	3.00	0.001	90	0.002	45	0.000	0	0.003	20	0.000	0	0.000	0

*** MOSES ***

7 November, 2017

Motion Analysis

MOSES Model Plot (Bow View)

Draft	= 15.5 Meters	Trim Angle	= 0.00 Deg.	GMT	= 6.3 Meters
Roll Gy. Radius	= 21.5 Meters	Pitch Gy. Radius	= 124.6 Meters	Yaw Gy. Radius	= 125.5 Meters
Heading	= 45.00 Deg.	Forward Speed	= 0.00 Knots	Linearization Based on 1/ 60	

+++ M O T I O N   R E S P O N S E   O P E R A T O R S +++

Results are in Body System

Of Point On Body FLNG At X = 191.3 Y = -0.0 Z = 24.4

Process is DEFAULT: Units Are Degrees, Meters, and M-Tons Unless Specified

E N C O U N T E R		Surge / Wave Ampl.		Sway / Wave Ampl.		Heave / Wave Ampl.		Roll / Wave Ampl.		Pitch / Wave Ampl.		Yaw / Wave Ampl.	
Frequency -(Rad/Sec)-	Period -(Sec)-	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase
0.2513	25.00	0.579	139	0.563	141	0.887	49	0.338	133	0.254	-40	0.125	-129
0.2565	24.50	0.559	142	0.546	144	0.867	51	0.359	133	0.257	-38	0.130	-125
0.2618	24.00	0.540	144	0.530	147	0.846	53	0.387	133	0.262	-35	0.134	-121
0.2674	23.50	0.524	147	0.515	150	0.826	55	0.426	133	0.267	-32	0.139	-117
0.2732	23.00	0.510	150	0.500	153	0.806	57	0.484	131	0.275	-29	0.144	-114
0.2793	22.50	0.498	152	0.485	156	0.787	59	0.572	127	0.284	-27	0.149	-111
0.2856	22.00	0.488	155	0.474	161	0.770	62	0.702	117	0.295	-24	0.154	-109
0.2922	21.50	0.480	157	0.477	165	0.755	66	0.799	94	0.309	-21	0.159	-107
0.2992	21.00	0.474	160	0.492	168	0.743	69	0.761	63	0.326	-18	0.163	-105
0.3065	20.50	0.471	162	0.494	168	0.735	73	0.564	35	0.347	-16	0.166	-103
0.3142	20.00	0.471	164	0.481	169	0.733	78	0.359	20	0.372	-14	0.170	-102
0.3222	19.50	0.451	168	0.454	173	0.705	82	0.190	13	0.384	-10	0.174	-97
0.3307	19.00	0.436	171	0.431	177	0.681	87	0.090	14	0.401	-7	0.178	-93
0.3396	18.50	0.412	176	0.403	-177	0.647	91	0.018	4	0.412	-2	0.182	-88
0.3491	18.00	0.392	180	0.379	-172	0.617	97	0.031	-161	0.429	1	0.185	-83
0.3590	17.50	0.364	-174	0.349	-167	0.577	103	0.071	-152	0.436	6	0.187	-77
0.3696	17.00	0.340	-169	0.322	-161	0.543	110	0.100	-150	0.452	11	0.190	-71
0.3808	16.50	0.307	-164	0.287	-155	0.495	116	0.125	-141	0.454	17	0.189	-64
0.3927	16.00	0.280	-158	0.257	-148	0.455	125	0.143	-137	0.467	23	0.190	-57
0.4054	15.50	0.244	-152	0.217	-142	0.397	132	0.155	-128	0.461	30	0.185	-49
0.4189	15.00	0.215	-145	0.182	-133	0.346	143	0.165	-122	0.470	37	0.183	-40
0.4333	14.50	0.182	-140	0.141	-126	0.281	153	0.167	-113	0.465	45	0.176	-30
0.4488	14.00	0.149	-135	0.098	-120	0.206	165	0.161	-104	0.453	54	0.166	-20
0.4654	13.50	0.118	-134	0.057	-120	0.121	-177	0.147	-94	0.431	62	0.152	-8
0.4833	13.00	0.092	-140	0.026	-153	0.044	-118	0.123	-84	0.389	70	0.133	3
0.5027	12.50	0.076	-154	0.039	150	0.099	-29	0.090	-74	0.319	78	0.109	17
0.5236	12.00	0.073	-167	0.066	148	0.181	-10	0.051	-67	0.219	87	0.080	31
0.5464	11.50	0.072	-168	0.086	161	0.221	0	0.016	-107	0.110	105	0.048	45
0.5712	11.00	0.065	-156	0.092	-179	0.201	14	0.041	-172	0.040	171	0.017	47
0.5984	10.50	0.056	-131	0.083	-155	0.136	37	0.072	-159	0.057	-101	0.016	-44
0.6283	10.00	0.039	-88	0.059	-127	0.069	75	0.088	-134	0.069	-56	0.035	-33
0.6614	9.50	0.018	-13	0.025	-97	0.036	161	0.078	-101	0.051	-8	0.041	-2
0.6981	9.00	0.018	101	0.009	161	0.039	-97	0.042	-63	0.027	52	0.034	38
0.7392	8.50	0.031	-173	0.030	-167	0.030	-14	0.009	-165	0.017	167	0.015	82
0.7854	8.00	0.027	-79	0.027	-110	0.018	84	0.044	-124	0.014	-67	0.007	-10
0.8378	7.50	0.016	35	0.004	-59	0.012	-115	0.035	-53	0.009	38	0.015	48
0.8976	7.00	0.015	-127	0.014	-118	0.009	19	0.008	-139	0.005	-98	0.004	118
0.9666	6.50	0.020	98	0.003	-28	0.011	118	0.027	-53	0.009	105	0.006	74
1.0472	6.00	0.018	-70	0.006	-38	0.005	-15	0.012	-63	0.005	-53	0.002	71
1.1424	5.50	0.004	-133	0.002	-65	0.003	9	0.004	160	0.001	103	0.001	124
1.2566	5.00	0.003	-39	0.001	83	0.001	59	0.005	121	0.000	0	0.001	-145
1.3963	4.50	0.006	178	0.002	127	0.006	12	0.006	37	0.001	118	0.001	90
1.5708	4.00	0.004	-72	0.002	-148	0.002	134	0.004	149	0.001	-98	0.001	170
2.0944	3.00	0.001	-118	0.002	-105	0.000	0	0.002	-78	0.000	0	0.002	171

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*************************************************************************************************************
*                                              ***  MOSES  ***                                              *
*                                              ---------------                         7 November, 2017    *
*          Motion Analysis                                                                                  *
*          MOSES Model Plot (Bow View)                                                                      *
*   Draft            =  15.5 Meters      Trim Angle       =   0.00 Deg.     GMT              =   6.3 Meters *
*   Roll Gy. Radius  =  21.5 Meters      Pitch Gy. Radius = 124.6 Meters    Yaw Gy. Radius   = 125.5 Meters *
*   Heading          =  90.00 Deg.       Forward Speed    =  0.00 Knots     Linearization Based on 1/ 60    *
*                                                                                                           *
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+++ M O T I O N   R E S P O N S E   O P E R A T O R S +++

Results are in Body System

Of Point On Body FLNG At X = 191.3 Y = -0.0 Z = 24.4

Process is DEFAULT: Units Are Degrees, Meters, and M-Tons Unless Specified

E N C O U N T E R		Surge / Wave Ampl.		Sway / Wave Ampl.		Heave / Wave Ampl.		Roll / Wave Ampl.		Pitch / Wave Ampl.		Yaw / Wave Ampl.	
Frequency -(Rad/Sec)-	Period -(Sec)-	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase
0.2513	25.00	0.024	179	0.882	91	1.007	0	0.615	83	0.001	0	0.001	-128
0.2565	24.50	0.023	179	0.877	91	1.011	0	0.682	81	0.001	-2	0.001	-130
0.2618	24.00	0.021	178	0.871	91	1.015	0	0.770	79	0.001	-4	0.001	-132
0.2674	23.50	0.020	177	0.863	91	1.019	0	0.880	75	0.001	-7	0.001	-133
0.2732	23.00	0.019	176	0.852	92	1.022	0	1.062	69	0.001	-9	0.002	-138
0.2793	22.50	0.017	176	0.847	93	1.026	0	1.201	58	0.001	-8	0.002	-145
0.2856	22.00	0.015	179	0.849	94	1.028	0	1.374	43	0.001	2	0.002	-158
0.2922	21.50	0.013	-174	0.864	96	1.029	0	1.494	23	0.001	17	0.003	-174
0.2992	21.00	0.013	-166	0.888	96	1.030	0	1.503	0	0.002	23	0.003	166
0.3065	20.50	0.014	-162	0.906	95	1.029	0	1.374	-22	0.003	18	0.002	148
0.3142	20.00	0.015	-162	0.906	93	1.030	0	1.172	-42	0.003	9	0.002	135
0.3222	19.50	0.015	-165	0.893	92	1.038	0	0.923	-58	0.004	0	0.002	128
0.3307	19.00	0.014	-168	0.875	92	1.045	0	0.703	-67	0.004	-8	0.001	128
0.3396	18.50	0.013	-170	0.856	92	1.054	0	0.536	-71	0.004	-15	0.001	131
0.3491	18.00	0.012	-172	0.839	92	1.063	0	0.419	-74	0.005	-22	0.001	136
0.3590	17.50	0.011	-173	0.822	92	1.076	0	0.325	-75	0.005	-29	0.001	141
0.3696	17.00	0.010	-174	0.805	92	1.089	0	0.255	-75	0.005	-36	0.001	145
0.3808	16.50	0.009	-174	0.787	92	1.106	-1	0.193	-74	0.005	-42	0.001	150
0.3927	16.00	0.008	-173	0.770	93	1.126	-1	0.145	-73	0.005	-50	0.001	153
0.4054	15.50	0.007	-170	0.749	93	1.152	-2	0.099	-69	0.005	-56	0.001	156
0.4189	15.00	0.006	-164	0.730	94	1.183	-3	0.064	-62	0.005	-64	0.001	160
0.4333	14.50	0.005	-155	0.708	94	1.220	-5	0.033	-40	0.005	-69	0.001	164
0.4488	14.00	0.004	-142	0.684	95	1.263	-8	0.023	29	0.005	-73	0.001	169
0.4654	13.50	0.004	-130	0.658	96	1.310	-12	0.044	68	0.005	-74	0.001	176
0.4833	13.00	0.005	-120	0.630	98	1.354	-17	0.070	80	0.006	-75	0.001	-174
0.5027	12.50	0.005	-113	0.601	99	1.378	-25	0.095	84	0.006	-80	0.001	-165
0.5236	12.00	0.005	-105	0.570	101	1.354	-35	0.114	87	0.007	-92	0.001	-156
0.5464	11.50	0.006	-101	0.538	104	1.242	-47	0.127	91	0.006	-101	0.001	-155
0.5712	11.00	0.007	-105	0.504	106	1.035	-60	0.135	97	0.006	-95	0.001	-162
0.5984	10.50	0.006	-111	0.468	110	0.788	-69	0.144	105	0.006	-105	0.001	-164
0.6283	10.00	0.005	-124	0.429	114	0.566	-74	0.152	112	0.005	-130	0.001	-177
0.6614	9.50	0.005	-122	0.389	119	0.399	-76	0.159	120	0.005	-142	0.001	-156
0.6981	9.00	0.005	-107	0.349	126	0.278	-74	0.165	128	0.004	-127	0.001	-162
0.7392	8.50	0.004	-102	0.308	134	0.185	-67	0.166	137	0.003	-137	0.001	-141
0.7854	8.00	0.004	-95	0.268	144	0.120	-58	0.162	148	0.003	-135	0.001	-131
0.8378	7.50	0.003	-113	0.229	156	0.078	-40	0.157	161	0.002	-174	0.001	-109
0.8976	7.00	0.004	-77	0.191	171	0.049	-36	0.147	175	0.002	-115	0.001	-120
0.9666	6.50	0.009	-74	0.149	-170	0.032	-10	0.128	-168	0.004	-79	0.001	-127
1.0472	6.00	0.006	-60	0.134	-123	0.018	23	0.125	-125	0.001	-87	0.001	-50
1.1424	5.50	0.002	-88	0.091	-102	0.004	54	0.091	-100	0.000	0	0.000	0
1.2566	5.00	0.002	101	0.062	-58	0.015	94	0.070	-57	0.001	73	0.000	0
1.3963	4.50	0.002	-174	0.010	70	0.001	124	0.005	-38	0.001	163	0.001	95
1.5708	4.00	0.002	-148	0.025	111	0.005	-12	0.030	107	0.001	-150	0.001	120
2.0944	3.00	0.000	0	0.007	106	0.000	0	0.008	107	0.000	0	0.000	0

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*****************************************************************************************************************
*                                                *** MOSES ***                                                  *
*                                                ---------------                          7 November, 2017      *
*          Motion Analysis                                                                                      *
*          MOSES Model Plot (Bow View)                                                                          *
*   Draft             =  15.5 Meters      Trim Angle       =   0.00 Deg.     GMT              =   6.3 Meters *
*   Roll Gy. Radius   =  21.5 Meters      Pitch Gy. Radius = 124.6 Meters    Yaw Gy. Radius   = 125.5 Meters *
*   Heading           = 135.00 Deg.       Forward Speed    =  0.00 Knots     Linearization Based on 1/ 60    *
*                                                                                                               *
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+++ M O T I O N R E S P O N S E O P E R A T O R S +++

Results are in Body System

Of Point On Body FLNG At X = 191.3 Y = -0.0 Z = 24.4

Process is DEFAULT: Units Are Degrees, Meters, and M-Tons Unless Specified

E N C O U N T E R		Surge / Wave Ampl.		Sway / Wave Ampl.		Heave / Wave Ampl.		Roll / Wave Ampl.		Pitch / Wave Ampl.		Yaw / Wave Ampl.	
Frequency -(Rad/Sec)-	Period -(Sec)-	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase
0.2513	25.00	0.588	-139	0.563	41	0.884	-49	0.336	29	0.259	40	0.126	-50
0.2565	24.50	0.575	-141	0.543	38	0.872	-51	0.353	27	0.266	38	0.131	-55
0.2618	24.00	0.563	-143	0.524	35	0.860	-53	0.376	24	0.274	36	0.136	-59
0.2674	23.50	0.552	-146	0.508	33	0.846	-55	0.409	20	0.284	33	0.141	-62
0.2732	23.00	0.542	-148	0.492	30	0.832	-57	0.459	15	0.294	31	0.146	-65
0.2793	22.50	0.532	-151	0.477	27	0.817	-60	0.535	6	0.306	28	0.151	-68
0.2856	22.00	0.522	-154	0.466	26	0.801	-63	0.641	-10	0.319	25	0.155	-71
0.2922	21.50	0.515	-157	0.468	25	0.783	-66	0.732	-40	0.334	22	0.159	-73
0.2992	21.00	0.508	-160	0.485	22	0.765	-69	0.690	-80	0.352	18	0.164	-75
0.3065	20.50	0.501	-163	0.490	17	0.745	-73	0.505	-120	0.371	15	0.168	-76
0.3142	20.00	0.494	-167	0.479	13	0.725	-77	0.324	-150	0.393	11	0.172	-78
0.3222	19.50	0.476	-172	0.450	8	0.698	-80	0.159	-167	0.409	6	0.176	-83
0.3307	19.00	0.457	-176	0.427	4	0.670	-84	0.069	164	0.427	1	0.181	-87
0.3396	18.50	0.434	178	0.398	0	0.639	-89	0.029	72	0.443	-3	0.184	-92
0.3491	18.00	0.412	172	0.375	-5	0.605	-93	0.062	17	0.461	-9	0.188	-97
0.3590	17.50	0.383	166	0.343	-10	0.568	-98	0.102	6	0.473	-16	0.189	-103
0.3696	17.00	0.353	159	0.317	-17	0.527	-104	0.135	1	0.486	-23	0.192	-109
0.3808	16.50	0.318	151	0.280	-23	0.482	-109	0.158	-9	0.494	-31	0.191	-116
0.3927	16.00	0.285	143	0.251	-31	0.433	-116	0.179	-17	0.502	-39	0.192	-123
0.4054	15.50	0.247	134	0.208	-39	0.379	-122	0.188	-29	0.502	-48	0.186	-131
0.4189	15.00	0.212	124	0.174	-49	0.316	-131	0.203	-37	0.503	-59	0.185	-140
0.4333	14.50	0.175	112	0.133	-61	0.247	-138	0.205	-49	0.496	-70	0.177	-150
0.4488	14.00	0.140	95	0.089	-76	0.168	-144	0.201	-62	0.483	-83	0.166	-161
0.4654	13.50	0.106	72	0.046	-99	0.088	-136	0.187	-77	0.458	-99	0.151	-173
0.4833	13.00	0.078	37	0.017	178	0.076	-75	0.162	-94	0.412	-118	0.132	171
0.5027	12.50	0.066	-13	0.041	95	0.161	-66	0.126	-113	0.333	-140	0.108	154
0.5236	12.00	0.070	-63	0.069	67	0.240	-85	0.081	-137	0.219	-165	0.078	134
0.5464	11.50	0.074	-99	0.088	44	0.268	-112	0.034	-173	0.096	179	0.046	109
0.5712	11.00	0.069	-125	0.093	21	0.233	-142	0.022	47	0.044	-128	0.014	62
0.5984	10.50	0.061	-145	0.083	-4	0.152	-168	0.058	-5	0.083	-118	0.018	-81
0.6283	10.00	0.050	-158	0.058	-32	0.069	179	0.084	-39	0.095	-139	0.036	-124
0.6614	9.50	0.030	-161	0.022	-64	0.045	-145	0.085	-71	0.069	-161	0.042	-159
0.6981	9.00	0.019	-133	0.012	90	0.060	-139	0.056	-108	0.032	-175	0.033	162
0.7392	8.50	0.031	-117	0.033	41	0.043	-156	0.008	-137	0.020	-132	0.013	114
0.7854	8.00	0.030	-129	0.027	-8	0.018	-159	0.039	-23	0.024	-129	0.009	-98
0.8378	7.50	0.016	-159	0.000	0	0.019	-117	0.044	-81	0.013	-163	0.015	-166
0.8976	7.00	0.017	-88	0.016	41	0.014	-153	0.003	-84	0.010	-92	0.003	108
0.9666	6.50	0.005	-104	0.001	-29	0.005	-66	0.035	-67	0.001	-74	0.007	-142
1.0472	6.00	0.021	-151	0.007	28	0.006	-133	0.013	-31	0.009	-145	0.003	-71
1.1424	5.50	0.004	-72	0.004	26	0.004	-171	0.007	-143	0.003	-111	0.001	-50
1.2566	5.00	0.010	-116	0.002	97	0.004	-8	0.010	12	0.003	-105	0.001	85
1.3963	4.50	0.010	-1	0.001	-103	0.005	173	0.003	-155	0.002	-18	0.002	-87
1.5708	4.00	0.007	-142	0.003	-170	0.004	53	0.006	61	0.002	-157	0.002	103
2.0944	3.00	0.001	-89	0.004	174	0.000	0	0.004	159	0.000	0	0.001	-76

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*****************************************************************************************************
*                                                *** MOSES ***                                      *
*                                                ---------------                7 November, 2017    *
*          Motion Analysis                                                                          *
*          MOSES Model Plot (Bow View)                                                              *
*   Draft            =  15.5 Meters      Trim Angle       =   0.00 Deg.     GMT            =   6.3 Meters *
*   Roll Gy. Radius  =  21.5 Meters      Pitch Gy. Radius = 124.6 Meters    Yaw Gy. Radius  = 125.5 Meters *
*   Heading          = 180.00 Deg.       Forward Speed    =  0.00 Knots     Linearization Based on 1/ 60   *
*                                                                                                   *
*****************************************************************************************************
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+++ M O T I O N R E S P O N S E O P E R A T O R S +++

Results are in Body System

Of Point On Body FLNG At X = 191.3 Y = -0.0 Z = 24.4

Process is DEFAULT: Units Are Degrees, Meters, and M-Tons Unless Specified

E N C O U N T E R		Surge / Wave Ampl.		Sway / Wave Ampl.		Heave / Wave Ampl.		Roll / Wave Ampl.		Pitch / Wave Ampl.		Yaw / Wave Ampl.	
Frequency -(Rad/Sec)-	Period -(Sec)-	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase
0.2513	25.00	0.742	-158	0.002	-100	0.768	-70	0.027	-103	0.343	20	0.001	-101
0.2565	24.50	0.711	-160	0.002	-107	0.744	-72	0.032	-111	0.347	17	0.001	-109
0.2618	24.00	0.681	-163	0.002	-112	0.719	-75	0.039	-118	0.352	14	0.002	-116
0.2674	23.50	0.652	-166	0.001	-112	0.692	-77	0.048	-127	0.358	11	0.002	-122
0.2732	23.00	0.626	-170	0.001	-85	0.664	-80	0.063	-137	0.366	7	0.002	-127
0.2793	22.50	0.602	-174	0.001	-25	0.634	-83	0.087	-149	0.376	3	0.002	-132
0.2856	22.00	0.579	-178	0.004	-20	0.603	-86	0.128	-166	0.387	0	0.002	-136
0.2922	21.50	0.558	177	0.008	-46	0.570	-91	0.184	162	0.401	-5	0.002	-138
0.2992	21.00	0.539	172	0.012	-87	0.536	-96	0.205	118	0.418	-10	0.002	-145
0.3065	20.50	0.523	167	0.012	-123	0.502	-101	0.163	79	0.439	-15	0.003	-155
0.3142	20.00	0.507	161	0.010	-144	0.468	-108	0.118	56	0.463	-21	0.003	-163
0.3222	19.50	0.466	155	0.009	-160	0.423	-112	0.090	39	0.468	-27	0.003	-174
0.3307	19.00	0.425	148	0.008	-174	0.375	-118	0.073	25	0.475	-35	0.003	175
0.3396	18.50	0.376	141	0.008	172	0.325	-121	0.060	11	0.473	-42	0.003	163
0.3491	18.00	0.328	132	0.007	160	0.271	-126	0.052	-1	0.471	-50	0.003	151
0.3590	17.50	0.271	124	0.007	147	0.221	-128	0.044	-14	0.457	-59	0.003	136
0.3696	17.00	0.217	113	0.006	133	0.164	-130	0.039	-28	0.442	-69	0.003	122
0.3808	16.50	0.159	105	0.006	119	0.124	-122	0.033	-43	0.410	-78	0.002	105
0.3927	16.00	0.104	90	0.005	103	0.087	-102	0.029	-58	0.378	-89	0.002	88
0.4054	15.50	0.053	81	0.004	87	0.100	-79	0.024	-75	0.330	-99	0.002	69
0.4189	15.00	0.011	1	0.004	69	0.132	-63	0.020	-94	0.277	-111	0.002	47
0.4333	14.50	0.038	-102	0.003	47	0.175	-66	0.016	-114	0.216	-120	0.001	23
0.4488	14.00	0.068	-124	0.002	21	0.213	-75	0.012	-138	0.153	-124	0.001	-5
0.4654	13.50	0.087	-141	0.002	-12	0.235	-88	0.008	-165	0.105	-114	0.001	-40
0.4833	13.00	0.092	-159	0.001	-66	0.233	-105	0.004	156	0.111	-90	0.000	0
0.5027	12.50	0.080	-178	0.001	-150	0.199	-122	0.002	79	0.157	-92	0.000	0
0.5236	12.00	0.052	169	0.001	141	0.141	-132	0.003	-13	0.184	-113	0.001	127
0.5464	11.50	0.028	-172	0.001	92	0.108	-122	0.004	-58	0.162	-139	0.001	76
0.5712	11.00	0.033	-133	0.001	48	0.128	-122	0.004	-101	0.104	-161	0.001	18
0.5984	10.50	0.049	-134	0.001	-15	0.124	-141	0.004	-153	0.055	-158	0.001	-51
0.6283	10.00	0.057	-147	0.001	-55	0.079	-161	0.002	153	0.058	-138	0.000	0
0.6614	9.50	0.043	-161	0.001	117	0.049	-152	0.003	7	0.054	-153	0.001	91
0.6981	9.00	0.028	-152	0.000	0	0.057	-148	0.003	-89	0.029	-167	0.000	0
0.7392	8.50	0.040	-148	0.000	0	0.036	-166	0.003	155	0.029	-146	0.000	0
0.7854	8.00	0.026	-161	0.001	54	0.029	-152	0.003	-34	0.022	-164	0.001	26
0.8378	7.50	0.028	-154	0.000	0	0.022	-168	0.002	146	0.017	-152	0.000	0
0.8976	7.00	0.014	-156	0.000	0	0.019	-155	0.002	-96	0.008	-169	0.000	0
0.9666	6.50	0.018	-160	0.000	0	0.013	-169	0.005	-33	0.011	-170	0.001	3
1.0472	6.00	0.018	-156	0.000	0	0.009	-167	0.002	-30	0.009	-164	0.000	0
1.1424	5.50	0.007	174	0.000	0	0.007	-158	0.003	-131	0.004	175	0.000	0
1.2566	5.00	0.010	-165	0.000	0	0.002	-161	0.003	-31	0.004	-166	0.000	0
1.3963	4.50	0.001	-172	0.001	-51	0.004	-174	0.002	-155	0.001	177	0.001	-71
1.5708	4.00	0.011	-124	0.002	-173	0.004	106	0.008	102	0.003	-132	0.002	131
2.0944	3.00	0.001	-70	0.002	165	0.000	0	0.004	140	0.001	-101	0.000	0

APPENDIX C

Wind Area Calculation

Item	X start fr bow (mm)	X end fr bow (mm)	Y start fr CL (mm)	Y end fr CL (mm)	Z start fr keel (mm)	Z end fr keel (mm)	Length (m)	Height (m)	Area (m^2)	Ch	Cs	Area x Ch x Cs (m^2)	Centroid (m)		
													X fr bow (+) to stern	Y fr CL (+) to stbd	Z fr WL (+) upward
Hull	0	381400			15500	38000	381.40	22.50	8581.50	1.00	1.00	8581.50	190.70		26.75
Turret support structure	0	-52040			20775	45200	52.04	24.43	1271.08	1.00	1.00	1271.08	26.02		32.99
Turret [1/6]	-50821	-11020			45061	53941	39.80	8.88	353.43	1.00	1.00	353.43	-30.92		49.50
Turret [2/6]	-50821	-15285			53941	60706	35.54	6.77	240.40	1.00	1.00	240.40	-33.05		57.32
Turret [3/6]	-50821	-18756			60706	69328	32.07	8.62	276.46	1.00	1.00	276.46	-34.79		65.02
Turret [4/6]	-50821	-22546			69328	74946	28.28	5.62	158.85	1.00	1.00	158.85	-36.68		72.14
Turret [5/6]	-49465	-24391			74946	81694	25.07	6.75	169.20	1.00	1.00	169.20	-36.93		78.32
Turret [6/6]	-48520	-26614			81694	88007	21.91	6.31	138.29	1.00	1.00	138.29	-37.57		84.85
Flare Tower	3324	21230			38500	131951	17.91	93.45	1673.33	1.30	1.50	3263.00	12.28		85.23
Block A [1]	31830	57732			38500	83401	25.90	44.90	1163.03	1.00	1.00	1163.03	44.78		60.95
Block A [2]	62300	90810			38500	73184	28.51	34.68	988.84	1.00	1.00	988.84	76.56		55.84
Block A [3]	71213	84169			73184	95634	12.96	22.45	290.86	1.00	1.00	290.86	77.69		84.41
Block A [4]	92327	107026			38500	68894	14.70	30.39	446.76	1.00	1.00	446.76	99.68		53.70
Block A [5]	108580	139154			38500	71906	30.57	33.41	1021.36	1.00	1.00	1021.36	123.87		55.20
Block A [6]	119760	122153			71930	88511	2.39	16.58	39.68	1.00	1.00	39.68	120.96		80.22
Block B [1]	143074	175159			38500	71924	32.09	33.42	1072.41	1.00	1.00	1072.41	159.12		55.21
Block B [2]	157140	161040			71916	89518	3.90	17.60	68.65	1.00	1.00	68.65	159.09		80.72
Block B [3]	176766	189829			38500	68931	13.06	30.43	397.52	1.00	1.00	397.52	183.30		53.72
Block B [4]	191355	221470			38500	73944	30.12	35.44	1067.40	1.00	1.00	1067.40	206.41		56.22
Padestal Crane A [1]	220105	222434			50065	84217	2.33	34.15	79.54	1.30	1.00	103.40	221.27		67.14
Padestal Crane A [2]	217634	225508			84217	97846	7.87	13.63	107.31	1.30	1.00	139.51	221.57		91.03
Padestal Crane A [3]	177861	217627			84616	87597	39.77	2.98	118.54	1.30	1.00	154.11	197.74		86.11
Block C [1]	225485	253815			38500	75958	28.33	37.46	1061.19	1.00	1.00	1061.19	239.65		57.23
Block C [2]	236963	242268			75954	89753	5.31	13.80	73.20	1.00	1.00	73.20	239.62		82.85
Block C [3]	255336	268250			38500	68966	12.91	30.47	393.44	1.00	1.00	393.44	261.79		53.73
Block C [4]	269800	290649			38500	68975	20.85	30.48	635.37	1.00	1.00	635.37	280.22		53.74
Block C [5]	272034	276836			68969	76358	4.80	7.39	35.48	1.00	1.00	35.48	274.44		72.66
Block C [6]	293691	318696			38500	57988	25.01	19.49	487.30	1.00	1.00	487.30	306.19		48.24
Block C [7]	294791	317491			57977	77237	22.70	19.26	437.20	1.00	1.00	437.20	306.14		67.61
Block C [8]	302491	310183			77237	96982	7.69	19.75	151.88	1.00	1.00	151.88	306.34		87.11
Padestal Crane B [1]	321969	325331			38500	85337	3.36	46.84	157.47	1.30	1.00	204.71	323.65		61.92
Padestal Crane B [2]	321215	328093			85337	98207	6.88	12.87	88.52	1.30	1.00	115.08	324.65		91.77
Padestal Crane B [3]	279684	321215			85011	87891	41.53	2.88	119.61	1.30	1.00	155.49	300.45		86.45
Living Quarter [1]	346226	370926			38500	84200	24.70	45.70	1128.79	1.00	1.00	1128.79	358.58		61.35
Living Quarter [2]	371026	377426			38500	83000	6.40	44.50	284.80	1.00	1.00	284.80	374.23		60.75
Living Quarter [3]	378876	398407			38500	62504	19.53	24.00	468.82	1.00	1.00	468.82	388.64		50.50
Crane Stern [1]	383660	387127			62504	79969	3.47	17.47	60.55	1.30	1.00	78.72	385.39		71.24
Crane Stern [2]	387127	415400			76344	79969	28.27	3.63	102.49	1.30	1.00	133.24	401.26		78.16
Helideck	355819	398270			83000	87500	42.45	4.50	191.03	1.20	1.30	298.01	377.04		85.25
								∑	25601.58			**27548.43**	**162.67**	**0.00**	**51.83**

Item	X start fr bow (mm)	X end fr bow (mm)	Y start fr CL (mm)	Y end fr CL (mm)	Z start fr keel (mm)	Z end fr keel (mm)	Length (m)	Height (m)	Area (m^2)	Ch	Cs	Area x Ch x Cs (m^2)	Centroid (m)		
													X fr bow (+) to stern	Y fr CL (+) to stbd	Z fr WL (+) upward
Hull			-32000	32000	15500	38000	64.00	22.50	1440.00	1.00	1.00	1440.00		0.00	
LQ [1]			-31079	31079	38500	84200	62.16	45.70	2840.62	1.00	1.00	2840.62		0.00	
Tower			-14420	-18351	84200	101238	3.93	17.04	66.98	1.00	1.00	66.98		-12.45	
Helideck			-3631	-46082	83000	87500	42.45	4.50	191.03	1.20	1.30	298.01		17.59	
Flare Tower			-31079	-78364	50046	132785	47.29	82.74	1052.01	1.30	1.50	2051.42		-50.45	
								∑	5590.64			**6697.02**	**0.00**	**-14.80**	**0.00**

APPENDIX D

Fatigue Load Case

Load Case Fatigue Analysis

Load Case	Environmental Direction (deg)	Hs (m)	Tp (sec)	Wind speed (m/s)	Current speed (m/s)
1	0	0.15	3.05	4.29	0.68
2	45	0.15	3.05	4.29	0.68
3	90	0.15	3.05	4.29	0.68
4	135	0.15	3.05	4.29	0.68
5	180	0.15	3.05	4.29	0.68
6	225	0.15	3.05	4.29	0.68
7	270	0.15	3.05	4.29	0.68
8	315	0.15	3.05	4.29	0.68
9	0	0.225	3.35	6.06	0.68
10	45	0.225	3.35	6.06	0.68
11	90	0.225	3.35	6.06	0.68
12	135	0.225	3.35	6.06	0.68
13	180	0.225	3.35	6.06	0.68
14	225	0.225	3.35	6.06	0.68
15	270	0.225	3.35	6.06	0.68
16	315	0.225	3.35	6.06	0.68
17	0	0.375	3.73	7.42	0.68
18	45	0.375	3.73	7.42	0.68
19	90	0.375	3.73	7.42	0.68
20	135	0.375	3.73	7.42	0.68
21	180	0.375	3.73	7.42	0.68
22	225	0.375	3.73	7.42	0.68
23	270	0.375	3.73	7.42	0.68
24	315	0.375	3.73	7.42	0.68
25	0	0.525	3.93	8.57	0.68
26	45	0.525	3.93	8.57	0.68
27	90	0.525	3.93	8.57	0.68
28	135	0.525	3.93	8.57	0.68
29	180	0.525	3.93	8.57	0.68
30	225	0.525	3.93	8.57	0.68
31	270	0.525	3.93	8.57	0.68
32	315	0.525	3.93	8.57	0.68
33	0	0.675	4.24	9.58	0.68
34	45	0.675	4.24	9.58	0.68
35	90	0.675	4.24	9.58	0.68
36	135	0.675	4.24	9.58	0.68
37	180	0.675	4.24	9.58	0.68
38	225	0.675	4.24	9.58	0.68
39	270	0.675	4.24	9.58	0.68
40	315	0.675	4.24	9.58	0.68
41	0	0.825	4.58	10.5	0.68
42	45	0.825	4.58	10.5	0.68
43	90	0.825	4.58	10.5	0.68
44	135	0.825	4.58	10.5	0.68
45	180	0.825	4.58	10.5	0.68
46	225	0.825	4.58	10.5	0.68

Load Case	Environmental Direction (deg)	Hs (m)	Tp (sec)	Wind speed (m/s)	Current speed (m/s)
47	270	0.825	4.58	10.5	0.68
48	315	0.825	4.58	10.5	0.68
49	0	0.975	4.77	11.34	0.68
50	45	0.975	4.77	11.34	0.68
51	90	0.975	4.77	11.34	0.68
52	135	0.975	4.77	11.34	0.68
53	180	0.975	4.77	11.34	0.68
54	225	0.975	4.77	11.34	0.68
55	270	0.975	4.77	11.34	0.68
56	315	0.975	4.77	11.34	0.68
57	45	1.125	4.9	12.12	0.68
58	90	1.125	4.9	12.12	0.68
59	135	1.125	4.9	12.12	0.68
60	180	1.125	4.9	12.12	0.68
61	270	1.125	4.9	12.12	0.68
62	45	1.275	5.38	12.86	0.68
63	90	1.275	5.38	12.86	0.68
64	135	1.275	5.38	12.86	0.68
65	180	1.275	5.38	12.86	0.68
66	90	1.425	5.56	13.55	0.68
67	135	1.425	5.56	13.55	0.68
68	180	1.425	5.56	13.55	0.68
69	0	1.575	6.05	14.22	0.68
70	45	1.575	6.05	14.22	0.68
71	90	1.575	6.05	14.22	0.68
72	135	1.575	6.05	14.22	0.68
73	180	1.575	6.05	14.22	0.68
74	315	1.575	6.05	14.22	0.68
75	90	1.725	6.35	14.85	0.68
76	135	1.725	6.35	14.85	0.68
77	180	1.725	6.35	14.85	0.68
78	135	0.15	9.67	0.0	0.0
79	135	0.225	9.74	0.0	0.0
80	135	0.375	9.5	0.0	0.0
81	135	0.15	11.64	0.0	0.0
82	135	0.225	12.02	0.0	0.0
83	135	0.375	12.22	0.0	0.0

APPENDIX E

Mooring Lines Fatigue Output

Case Study 1 – Base case

Line Number	Line Section	Damage	Life (year)	Arc Length (m)	FoS
Mooring Leg 1	Top chain	1.80E-04	5568.91	99.91	185.6
	Steel wire	4.96E-08	20159058.10	489.95	671968.6
	Bottom chain	2.18E-04	4602.76	826.41	153.4
Mooring Leg 2	Top chain	1.84E-04	5448.56	94.89	181.6
	Steel wire	4.95E-08	20218888.70	546.02	673963.0
	Bottom chain	2.20E-04	4547.26	830.41	151.6
Mooring Leg 3	Top chain	1.88E-04	5329.70	99.91	177.7
	Steel wire	5.02E-08	19938695.70	523.99	664623.2
	Bottom chain	2.23E-04	4485.81	826.41	149.5
Mooring Leg 4	Top chain	1.94E-04	5165.53	99.91	172.2
	Steel wire	5.17E-08	19359285.55	513.98	645309.5
	Bottom chain	2.30E-04	4344.83	826.41	144.8
Mooring Leg 5	Top chain	3.13E-04	3191.51	0.00	106.4
	Steel wire	7.04E-08	14194558.87	574.06	473152.0
	Bottom chain	3.35E-04	2983.33	826.41	99.4
Mooring Leg 6	Top chain	2.97E-04	3363.14	2.51	112.1
	Steel wire	6.49E-08	15409427.82	588.08	513647.6
	Bottom chain	3.14E-04	3182.19	826.41	106.1
Mooring Leg 7	Top chain	2.85E-04	3508.40	2.51	116.9
	Steel wire	5.96E-08	16774249.90	586.08	559141.7
	Bottom chain	2.94E-04	3405.18	826.41	113.5
Mooring Leg 8	Top chain	2.77E-04	3614.95	1.51	120.5
	Steel wire	5.47E-08	18265933.00	578.07	608864.4
	Bottom chain	2.73E-04	3663.54	826.41	122.1
Mooring Leg 9	Top chain	2.24E-04	4473.85	99.90	149.1
	Steel wire	5.87E-08	17031388.29	479.93	567712.9
	Bottom chain	2.74E-04	3651.18	826.40	121.7
Mooring Leg 10	Top chain	2.35E-04	4259.62	99.90	142.0
	Steel wire	6.25E-08	16006118.87	558.04	533537.3
	Bottom chain	2.86E-04	3491.00	826.40	116.4
Mooring Leg 11	Top chain	2.44E-04	4092.07	92.87	136.4
	Steel wire	6.61E-08	15136901.28	578.06	504563.4
	Bottom chain	2.99E-04	3345.88	826.40	111.5
Mooring Leg 12	Top chain	2.54E-04	3942.10	88.86	131.4
	Steel wire	7.00E-08	14290144.69	642.15	476338.2
	Bottom chain	3.13E-04	3199.55	826.40	106.7

Case Study 2 – Pretension 14% MBL

Line Number	Line Section	Damage (yearly)	Life (year)	Arc Length (m)	FoS
Mooring Leg 1	Top chain	1.52E-04	6570.94	123.38	219.0
	Steel wire	5.28E-08	18949385.38	791.80	631646.2
	Bottom chain	2.50E-04	4003.90	849.88	133.5
Mooring Leg 2	Top chain	1.55E-04	6452.13	123.38	215.1
	Steel wire	6.65E-08	15037482.11	747.74	501249.4
	Bottom chain	2.89E-04	3464.87	849.88	115.5
Mooring Leg 3	Top chain	1.68E-04	5965.56	123.38	198.9
	Steel wire	6.33E-08	15795221.26	771.77	526507.4
	Bottom chain	2.89E-04	3461.85	851.88	115.4
Mooring Leg 4	Top chain	1.83E-04	5465.11	123.38	182.2
	Steel wire	6.01E-08	16640917.94	797.81	554697.3
	Bottom chain	2.74E-04	3655.58	849.88	121.9
Mooring Leg 5	Top chain	2.76E-04	3617.10	123.38	120.6
	Steel wire	1.26E-07	7926318.06	759.76	264210.6
	Bottom chain	5.12E-04	1951.59	851.88	65.1
Mooring Leg 6	Top chain	2.57E-04	3885.64	123.38	129.5
	Steel wire	1.21E-07	8289676.15	753.75	276322.5
	Bottom chain	5.05E-04	1979.49	849.88	66.0
Mooring Leg 7	Top chain	2.31E-04	4327.12	123.38	144.2
	Steel wire	1.11E-07	8986105.56	797.81	299536.9
	Bottom chain	4.74E-04	2111.27	849.88	70.4
Mooring Leg 8	Top chain	2.11E-04	4735.53	123.38	157.9
	Steel wire	1.04E-07	9637811.18	751.75	321260.4
	Bottom chain	4.18E-04	2391.58	857.88	79.7
Mooring Leg 9	Top chain	1.41E-04	7071.50	123.37	235.7
	Steel wire	1.01E-07	9860200.00	817.83	328673.3
	Bottom chain	4.34E-04	2302.52	849.87	76.8
Mooring Leg 10	Top chain	1.47E-04	6789.47	123.37	226.3
	Steel wire	1.17E-07	8514528.28	781.78	283817.6
	Bottom chain	4.99E-04	2002.97	857.87	66.8
Mooring Leg 11	Top chain	1.56E-04	6418.64	123.37	214.0
	Steel wire	1.34E-07	7438901.06	817.83	247963.4
	Bottom chain	5.51E-04	1814.20	849.87	60.5
Mooring Leg 12	Top chain	1.65E-04	6052.15	123.37	201.7
	Steel wire	1.17E-07	8564612.36	797.80	285487.1
	Bottom chain	4.87E-04	2052.71	857.87	68.4

Case Study 3 – Pretension 22% MBL

Line Number	Line Section	Damage	Life (year)	Arc Length (m)	FoS
Mooring Leg 1	Top chain	3.74E-04	2676.66	86.19	89.2
	Steel wire	1.12E-07	8896035.01	566.35	296534.5
	Bottom chain	4.65E-04	2148.64	812.69	71.6
Mooring Leg 2	Top chain	3.71E-04	2696.86	86.19	89.9
	Steel wire	1.10E-07	9131007.94	564.35	304366.9
	Bottom chain	4.61E-04	2167.37	812.69	72.2
Mooring Leg 3	Top chain	3.72E-04	2690.45	86.19	89.7
	Steel wire	1.09E-07	9188097.05	566.35	306269.9
	Bottom chain	4.61E-04	2168.39	812.69	72.3
Mooring Leg 4	Top chain	3.72E-04	2685.62	86.19	89.5
	Steel wire	1.09E-07	9210040.09	562.35	307001.3
	Bottom chain	4.62E-04	2165.56	812.69	72.2
Mooring Leg 5	Top chain	3.28E-04	3045.31	86.20	101.5
	Steel wire	9.58E-08	10435268.23	690.53	347842.3
	Bottom chain	4.17E-04	2398.93	812.70	80.0
Mooring Leg 6	Top chain	3.23E-04	3098.26	86.20	103.3
	Steel wire	9.35E-08	10694005.18	740.60	356466.8
	Bottom chain	4.11E-04	2432.13	812.69	81.1
Mooring Leg 7	Top chain	3.18E-04	3149.15	85.20	105.0
	Steel wire	9.05E-08	11044171.82	706.55	368139.1
	Bottom chain	4.01E-04	2492.42	812.69	83.1
Mooring Leg 8	Top chain	3.08E-04	3249.45	86.20	108.3
	Steel wire	8.75E-08	11431812.09	714.56	381060.4
	Bottom chain	3.90E-04	2565.76	812.69	85.5
Mooring Leg 9	Top chain	3.67E-04	2721.43	86.19	90.7
	Steel wire	9.96E-08	10036333.94	660.48	334544.5
	Bottom chain	4.63E-04	2161.88	812.69	72.1
Mooring Leg 10	Top chain	3.72E-04	2690.74	86.19	89.7
	Steel wire	1.02E-07	9829317.17	668.49	327643.9
	Bottom chain	4.69E-04	2131.85	812.69	71.1
Mooring Leg 11	Top chain	3.77E-04	2655.24	86.19	88.5
	Steel wire	1.04E-07	9648627.55	654.47	321620.9
	Bottom chain	4.74E-04	2108.86	812.69	70.3
Mooring Leg 12	Top chain	3.83E-04	2609.95	86.19	87.0
	Steel wire	1.09E-07	9214504.50	644.45	307150.1
	Bottom chain	4.91E-04	2034.61	812.69	67.8

Case Study 4 – 50% Water depth

Line Number	Line Section	Damage	Life (year)	Arc Length (m)	FoS
Mooring Leg 1	Top chain	1.24E-04	8076.27	49.57	269.2
	Steel wire	2.75E-08	36384904.57	411.57	1212830.2
	Bottom chain	1.61E-04	6192.97	423.51	206.4
Mooring Leg 2	Top chain	1.27E-04	7891.85	49.57	263.1
	Steel wire	2.78E-08	35967700.25	411.57	1198923.3
	Bottom chain	1.65E-04	6043.51	429.47	201.5
Mooring Leg 3	Top chain	1.31E-04	7652.05	49.57	255.1
	Steel wire	2.91E-08	34308920.98	411.57	1143630.7
	Bottom chain	1.71E-04	5848.63	427.48	195.0
Mooring Leg 4	Top chain	1.37E-04	7290.54	49.57	243.0
	Steel wire	3.05E-08	32777279.90	411.57	1092576.0
	Bottom chain	1.78E-04	5629.67	427.48	187.7
Mooring Leg 5	Top chain	2.30E-04	4346.67	49.57	144.9
	Steel wire	5.38E-08	18579150.07	411.57	619305.0
	Bottom chain	2.97E-04	3363.62	425.50	112.1
Mooring Leg 6	Top chain	2.16E-04	4634.32	49.57	154.5
	Steel wire	4.99E-08	20057592.38	411.57	668586.4
	Bottom chain	2.82E-04	3548.75	435.44	118.3
Mooring Leg 7	Top chain	2.01E-04	4963.20	49.57	165.4
	Steel wire	4.59E-08	21799010.13	411.57	726633.7
	Bottom chain	2.63E-04	3805.78	429.48	126.9
Mooring Leg 8	Top chain	1.88E-04	5328.41	49.57	177.6
	Steel wire	4.22E-08	23673351.67	411.57	789111.7
	Bottom chain	2.43E-04	4112.95	445.39	137.1
Mooring Leg 9	Top chain	1.55E-04	6441.18	49.56	214.7
	Steel wire	3.36E-08	29799553.14	411.56	993318.4
	Bottom chain	2.02E-04	4951.70	423.50	165.1
Mooring Leg 10	Top chain	1.62E-04	6165.48	49.56	205.5
	Steel wire	3.59E-08	27868754.46	411.56	928958.5
	Bottom chain	2.12E-04	4717.90	423.50	157.3
Mooring Leg 11	Top chain	1.68E-04	5936.91	49.56	197.9
	Steel wire	3.84E-08	26058401.97	411.56	868613.4
	Bottom chain	2.22E-04	4498.68	427.48	150.0
Mooring Leg 12	Top chain	1.77E-04	5646.12	49.56	188.2
	Steel wire	4.07E-08	24599516.90	411.56	819983.9
	Bottom chain	2.32E-04	4308.91	433.45	143.6

Case Study 5 – 150% Water depth

Line Number	Line Section	Damage	Life (year)	Arc Length (m)	FoS
Mooring Leg 1	Top chain	2.82E-04	3546.96	149.50	118.2
	Steel wire	9.15E-08	10928799.61	652.77	364293.3
	Bottom chain	2.79E-04	3584.64	1238.50	119.5
Mooring Leg 2	Top chain	2.88E-04	3471.86	149.50	115.7
	Steel wire	9.35E-08	10697667.21	686.75	356588.9
	Bottom chain	2.87E-04	3478.59	1238.50	116.0
Mooring Leg 3	Top chain	2.94E-04	3395.59	149.50	113.2
	Steel wire	9.50E-08	10527798.06	696.75	350926.6
	Bottom chain	2.95E-04	3394.51	1238.50	113.2
Mooring Leg 4	Top chain	3.01E-04	3321.02	149.50	110.7
	Steel wire	9.78E-08	10222304.71	714.74	340743.5
	Bottom chain	3.04E-04	3291.71	1238.50	109.7
Mooring Leg 5	Top chain	5.22E-04	1915.24	149.50	63.8
	Steel wire	1.91E-07	5240470.10	762.72	174682.3
	Bottom chain	4.71E-04	2125.28	1238.50	70.8
Mooring Leg 6	Top chain	5.03E-04	1986.83	149.50	66.2
	Steel wire	1.81E-07	5526597.55	766.72	184219.9
	Bottom chain	4.44E-04	2253.59	1238.50	75.1
Mooring Leg 7	Top chain	4.80E-04	2083.43	149.50	69.4
	Steel wire	1.71E-07	5846339.22	774.71	194878.0
	Bottom chain	4.18E-04	2392.37	1238.50	79.7
Mooring Leg 8	Top chain	4.57E-04	2186.82	147.50	72.9
	Steel wire	1.62E-07	6185277.66	740.73	206175.9
	Bottom chain	3.93E-04	2545.70	1238.50	84.9
Mooring Leg 9	Top chain	5.05E-04	1980.01	148.50	66.0
	Steel wire	1.74E-07	5736059.11	724.74	191202.0
	Bottom chain	3.08E-04	3246.48	1238.50	108.2
Mooring Leg 10	Top chain	5.22E-04	1916.33	148.50	63.9
	Steel wire	1.82E-07	5484188.03	726.73	182806.3
	Bottom chain	3.22E-04	3101.20	1238.50	103.4
Mooring Leg 11	Top chain	5.36E-04	1865.78	149.50	62.2
	Steel wire	1.89E-07	5294315.35	716.74	176477.2
	Bottom chain	3.36E-04	2976.00	1238.50	99.2
Mooring Leg 12	Top chain	5.43E-04	1842.65	149.50	61.4
	Steel wire	1.93E-07	5172113.55	696.75	172403.8
	Bottom chain	3.42E-04	2924.94	1238.50	97.5

Case Study 6 – Wave load component: 1st order wave load

Line Number	Line Section	Damage	Life (year)	Arc Length (m)	FoS
Mooring Leg 1	Top chain	1.75E-04	5720.11	99.91	190.7
	Steel wire	2.94E-08	34062700.03	582.07	1135423.3
	Bottom chain	2.15E-04	4647.23	828.41	154.9
Mooring Leg 2	Top chain	1.49E-04	6719.86	84.85	224.0
	Steel wire	2.06E-08	48528391.53	283.66	1617613.1
	Bottom chain	1.76E-04	5676.91	826.41	189.2
Mooring Leg 3	Top chain	1.25E-04	8000.66	99.91	266.7
	Steel wire	1.44E-08	69243101.40	107.42	2308103.4
	Bottom chain	1.41E-04	7105.19	826.41	236.8
Mooring Leg 4	Top chain	9.83E-05	10168.88	99.91	339.0
	Steel wire	9.69E-09	103243302.23	283.66	3441443.4
	Bottom chain	1.12E-04	8953.66	826.41	298.5
Mooring Leg 5	Top chain	8.24E-04	1212.99	1.51	40.4
	Steel wire	2.65E-07	3767728.61	728.28	125591.0
	Bottom chain	8.43E-04	1186.71	828.41	39.6
Mooring Leg 6	Top chain	8.19E-04	1220.97	4.52	40.7
	Steel wire	2.65E-07	3767943.46	770.34	125598.1
	Bottom chain	8.40E-04	1190.46	828.41	39.7
Mooring Leg 7	Top chain	8.08E-04	1238.19	1.51	41.3
	Steel wire	2.61E-07	3829691.86	728.28	127656.4
	Bottom chain	8.27E-04	1208.99	830.41	40.3
Mooring Leg 8	Top chain	7.89E-04	1267.08	0.00	42.2
	Steel wire	2.54E-07	3940812.13	754.31	131360.4
	Bottom chain	8.10E-04	1234.95	826.41	41.2
Mooring Leg 9	Top chain	1.05E-04	9485.91	99.90	316.2
	Steel wire	1.23E-08	81403095.13	377.79	2713436.5
	Bottom chain	1.18E-04	8469.56	826.40	282.3
Mooring Leg 10	Top chain	1.35E-04	7398.02	99.90	246.6
	Steel wire	1.82E-08	54894828.45	351.75	1829827.6
	Bottom chain	1.52E-04	6580.94	826.40	219.4
Mooring Leg 11	Top chain	1.65E-04	6076.64	97.89	202.6
	Steel wire	2.53E-08	39458274.14	165.49	1315275.8
	Bottom chain	1.89E-04	5281.89	826.40	176.1
Mooring Leg 12	Top chain	1.93E-04	5176.09	76.81	172.5
	Steel wire	3.50E-08	28568877.58	610.11	952295.9
	Bottom chain	2.31E-04	4320.59	826.40	144.0

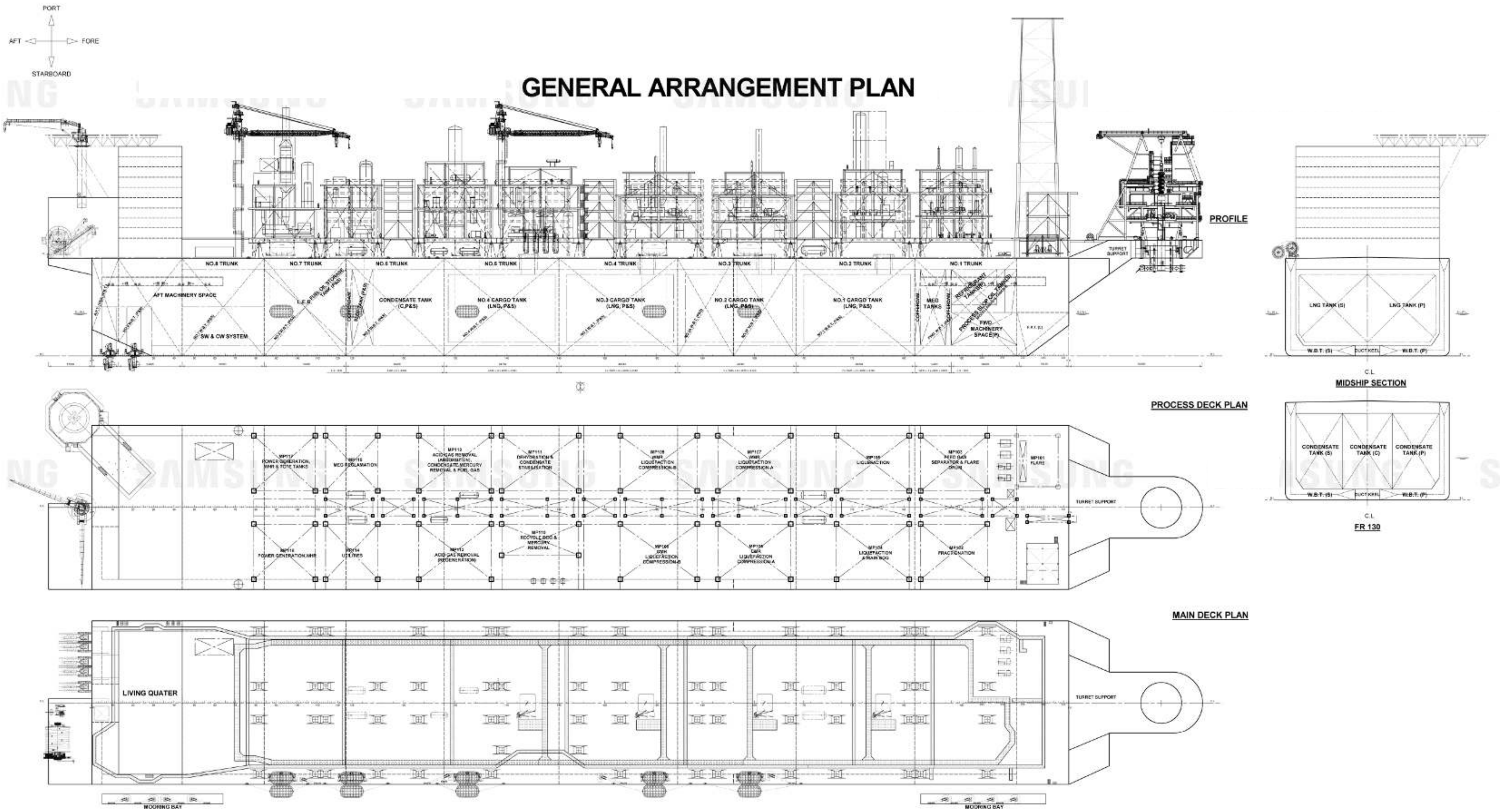
Case Study 7 – Wave load component: 2nd order wave load

Line Number	Line Section	Damage	Life (year)	Arc Length (m)	FoS
Mooring Leg 1	Top chain	1.64E-04	6102.26	55.73	203.4
	Steel wire	4.08E-08	24535373.75	526.00	817845.8
	Bottom chain	1.97E-04	5080.02	826.41	169.3
Mooring Leg 2	Top chain	1.70E-04	5899.64	91.87	196.7
	Steel wire	4.15E-08	24120479.75	449.89	804016.0
	Bottom chain	2.00E-04	4994.68	826.41	166.5
Mooring Leg 3	Top chain	1.74E-04	5743.22	99.91	191.4
	Steel wire	4.28E-08	23341574.25	495.95	778052.5
	Bottom chain	2.05E-04	4882.45	826.41	162.7
Mooring Leg 4	Top chain	1.80E-04	5563.28	99.91	185.4
	Steel wire	4.46E-08	22422778.92	431.87	747426.0
	Bottom chain	2.12E-04	4723.87	826.41	157.5
Mooring Leg 5	Top chain	3.09E-04	3235.27	6.53	107.8
	Steel wire	7.58E-08	13194109.17	203.55	439803.6
	Bottom chain	3.48E-04	2872.47	828.41	95.7
Mooring Leg 6	Top chain	2.94E-04	3404.45	8.53	113.5
	Steel wire	7.03E-08	14227870.01	201.55	474262.3
	Bottom chain	3.28E-04	3046.42	826.41	101.5
Mooring Leg 7	Top chain	2.77E-04	3610.55	2.51	120.4
	Steel wire	6.50E-08	15376281.21	193.54	512542.7
	Bottom chain	3.07E-04	3255.23	826.41	108.5
Mooring Leg 8	Top chain	2.62E-04	3812.55	5.52	127.1
	Steel wire	6.01E-08	16634085.29	181.52	554469.5
	Bottom chain	2.87E-04	3488.08	826.41	116.3
Mooring Leg 9	Top chain	1.94E-04	5156.67	97.89	171.9
	Steel wire	4.70E-08	21291372.73	493.95	709712.4
	Bottom chain	2.29E-04	4366.42	826.40	145.5
Mooring Leg 10	Top chain	1.97E-04	5070.75	99.90	169.0
	Steel wire	4.94E-08	20248422.73	552.03	674947.4
	Bottom chain	2.39E-04	4180.10	826.40	139.3
Mooring Leg 11	Top chain	2.07E-04	4835.04	99.90	161.2
	Steel wire	5.21E-08	19205149.62	517.98	640171.7
	Bottom chain	2.49E-04	4018.81	826.40	134.0
Mooring Leg 12	Top chain	2.16E-04	4631.48	91.87	154.4
	Steel wire	5.46E-08	18318024.21	594.08	610600.8
	Bottom chain	2.58E-04	3876.22	826.40	129.2

APPENDIX F

General Arrangement

GENERAL ARRANGEMENT PLAN



AUTHOR BIOGRAPHY

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