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MASTER THESIS

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ABSTRACT

This thesis is centered on the study and comparison of different mooring/anchoring systems for offshore vessels in deep waters. FPSO's (Floating, Production, Storage and Offloading platforms), Light Weight Intervention vessels (LWI); Semi-submersible platforms and Mobile Offshore Drilling Units (MODU) make use of efficient mooring/anchoring systems to provide a connection between the floating vessel and the sea bed. If a good mooring/anchoring system is not in place, the offshore vessel can drift off location and consequently cause damage to the vessel, riser, drill pipe and other associated equipment, thereby, compromising the safety of the asset and offshore personnel. Safety of the mooring/anchoring system is essential in order to guarantee successful marine operations.

It is pertinent to have a strong mooring/anchoring system in order to secure the vessel against environmental forces and unplanned impact. As offshore technology is moving into deeper and deeper waters, there is an increasing challenge in the design of mooring/anchoring systems for offshore vessels. New technology, concepts, materials and sophisticated models showcasing the interaction between vessels and environment have been introduced. In this thesis, an investigation of the design and characteristics of different mooring/anchoring systems was carried out.

The major tasks carried out in this thesis are listed below:

- Review of different mooring and anchoring systems for offshore vessels.
- Use of OrcaFlex software to perform dynamic analysis of different *mooring lines* to determine the design criteria for a range of mooring/anchoring systems for different offshore vessels.
- Performing a SWOT analysis of the mooring line materials.
- Calculating different forces and tensions on the mooring lines based on the prevailing environmental conditions in deep waters.

The write-up begins with a review of different mooring and anchoring systems for offshore vessels followed by a SWOT (Strength, Weakness, Opportunities and Threats) analysis of different mooring line materials. A review of the regulations and standards governing the design and installation of mooring systems for offshore applications in different environments was also carried out.

Different combination of mooring lines were used in this analysis to secure the vessel in position and the tensions obtained across the arc length of each mooring line are presented in the results. Three mooring line configuration cases were analyzed in this thesis. In the three cases, the offshore vessel is moored with eight symmetric mooring lines spaced 45° apart. The mooring lines configuration is Chain-Fiber rope–Chain in Case 1, Wire rope-Chain in Case 2, and Chain-Wire rope-Chain in case 3. The mooring geometry for all the cases is a catenary mooring system. The simulation uses regular waves acting on the vessel for the duration of 115 seconds. The mooring system employs a turret, located at the vessel's moonpool. Since all mooring lines are connected to the turret, the vessel is free to rotate about the turret-wellhead axis and head into oncoming seas, regardless of direction. Thrusters are provided at the bow and stern to assist in maintaining a desired heading. The chain table connecting the mooring line to the turret is above the waterline. The wave theory used in the analysis is Dean Stream. The vessel used for the modelling is 103m long and weighs 8800 tonnes.

From the analysis carried out, it was observed that the maximum tension occurs at the turret end of the mooring lines. This is as a result of the vessel motions induced by environmental forces. The tensions obtained in Case 3 are quite high when compared to case1 and case 2, but are still within acceptable limits as they are less than the minimum breaking loads of the mooring line materials used. It was also observed that Chain impose an enormous weight on the mooring line compared to fiber ropes consequently resulting to increased tension in the lines. The use of synthetic fiber rope in the configuration reduced the mooring weight and increases flexibility, thereby reducing the mooring line tensions. The advantages of each mooring/anchoring system are optimized while dispelling their disadvantages. Recommendations as regards the selection of mooring/anchoring systems for different offshore vessels operating in different environments are presented in this report. The results of the dynamic analysis can be used to determine the design criteria for a range of mooring/anchoring systems for different offshore vessels.

Keywords: Offshore vessels, Mooring lines, Anchors, Tensions, Chain, Wire rope, Fiber rope.

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This work could only be done through the help and support of God. I would like to dedicate this work to His Glory.

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Abbreviations

ALS	Accidental Limit State
API	American Petroleum Institute
DNV	Det Norske Veritas
FLS	Fatigue Limit state
FPSO	Floating Production, Storage, and Offloading Unit
FPU	Floating Production Unit
GOM	Gulf of Mexico
JONSWAP	Joint North Sea Wave Project
LRFD	Load Resistance Factor Design
MBR	Minimum Bend Radius
MODU	Mobile Offshore Drilling Units
NMD	Norwegian Maritime Directorate
NPD	Norwegian Petroleum Directorate
NSA	Norwegian Safety Authority
RAO	Response Amplitude Operator
ULS	Ultimate Limit State
WSD	Working Stress Design

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CHAPTER ONE

INTRODUCTION

2.0 Background

This thesis is centered on the study of anchoring/mooring systems for deep water offshore vessels. As a result of the increasing world demand for oil and gas, offshore technology is advancing towards deep and ultra deep waters. The exploration, production and transportation of oil and gas usually require the use of offshore vessels for different purposes. Offshore vessels employ the services of mooring/anchoring systems to secure the vessel to the sea floor, thereby protecting the vessel from environmental forces. Offshore vessels utilizing these mooring/anchoring systems range from drilling vessels to floating production vessels (FPSOs). It is important to have an efficient mooring/anchoring system in place so as to withstand all the mooring loads and vertical loads on the anchors. Mooring/anchoring systems provide a strong connection between the floating vessel and the sea floor. If a good mooring/anchoring system is not in place, the offshore vessel can drift off location and consequently cause damage to the vessel, riser, drill pipe and other associated equipment, thereby, compromising the safety of the asset and personnel in the long run.

1.1 Objective of the thesis

The objective of the thesis is to carry out an investigation of the design and characteristics of different mooring/anchoring systems for deepwater offshore vessels. The main task is to:

- Review different mooring and anchoring systems for offshore vessels.
- Review the effects of Soil mechanics on anchor design
- Carry out a SWOT analysis of different mooring line materials (Chain, Wire rope, and Synthetic polyester fiber ropes)
- Use OrcaFlex software to carry out dynamic analysis on different mooring based on different environmental conditions.
- Determine the effective tension in the mooring lines from the dynamic analysis
- Use the result obtained from the dynamic analysis to determine the design criteria for a range of mooring/anchoring systems for different offshore vessels.

1.2 Scope of the thesis

Different kinds of anchoring/mooring systems will be studied in this thesis and a SWOT analysis will be carried out to compare the capabilities of different anchors and mooring line components in terms of station-keeping capabilities. OrcaFlex will also be used to carry out dynamic analysis of the different mooring systems for different offshore vessels using different parameters. A limitation in this thesis is that there are several anchor/anchoring systems manufacturers in the market today, for example Vryhof Anchors, Bruce anchors, Intermoor etc. who manufacture anchors based on the same design, standard and specification. In this thesis, the anchors manufactured by Vryhof Anchors are analysed.

1.3 Thesis Overview

Marine operations play a vital role in deep waters oil and gas field developments. Over the past years, the interest in the exploration of oil and gas fields in deep and ultra deep waters has significantly increased. As the water depth increases, the mooring loads and the loads on the anchoring system increases simultaneously. Mooring/Anchoring systems in deep and ultra deep waters must support high sustained tension in the mooring lines. In designing a mooring system, it is pertinent to determine the cable tensions, possible range of vessel excursions, and the different failure modes; such as breaking of the cable and dragging of the anchors.

In this thesis, analysis will be carried out to check out different mooring/anchoring systems adequacy and station keeping capabilities.

In Chapter one, historical background and a review of mooring/anchoring systems is presented. A brief discussion of the types of anchors and mooring components is also presented. The objective and scope of the thesis is also contained in Chapter one.

Chapter two presents a detailed SWOT (Strength, Weakness, Opportunities and Threat) analysis of the different anchoring/mooring systems. The comparison is based on system design and description, installation and retrieval, deployment vessels and limitations. Performance of anchors in different soil conditions is also presented in chapter two. Emphasis is placed on catenary mooring and taut leg mooring. A literature review of state- of-the- art development in the mooring industry is also discussed.

In Chapter three, regulations guiding the use of mooring and anchoring systems in different offshore environments are discussed. The several guidelines provided for installation and usage of mooring systems for offshore vessels in the oil and gas industry are reviewed in this chapter. Safety factors for intact and damaged conditions are compared in chapter three.

In Chapter four, an in-depth discussion on the characteristics of mooring line is presented. The Minimum Breaking Loads (MBL) and other mechanical properties of chain, wire rope and fiber ropes were considered.

In Chapter five, dynamic analysis of different *mooring lines/anchoring systems* is carried out. OrcaFlex software is used to carry out dynamic analysis on different mooring systems. The OrcaFlex model is presented as well as the analysis procedure. The derivation of the catenary equation is also contained in chapter three.

Chapter six presents the results of the analysis and engineering discussion while chapter seven enumerates the conclusions and recommendations.

1.4 Historical background

History traces the use of anchors to China as far back as 2,000BC, though it is quite probable that they were used prior to this. At a time, the general practice was to use large stones, basket of stones, bags of sand or even logs of wood loaded with lead which were fastened to the lines. It was this weight as well as a certain degree of friction on the bottom, which secured a vessel in position (Vryhof Anchors, 2010).

With the introduction of iron into anchor construction, teeth or flukes were built on the anchor, allowing penetration into sea bed, thus offering additional stability. Yet, these primitive anchors were of poor construction and often broke under pressure and excessive vertical loads.

Curved arms were introduced in 1813, and from 1852, the so called “Admiralty Anchor” was used for ships of the Royal Navy. Another refinement in the 19th century was the elimination of the stock, the crosspiece at the top of an anchor, which ensured that the positioning of the anchor would allow flukes to penetrate the soil. A stockless anchor was invented in 1821 and became popular, primarily as a result of the case of handling and stowing qualities still valued today. A large number of anchor types have been designed and commercialized over the years (Vryhof Anchors, 2010).

1.5 Literature Review

Marine operations in deep waters require a robust mooring system with large size mooring/anchoring elements. These include anchors with high holding capacities and strong mooring components. Development of new anchoring systems such as vertical or near-vertical lift anchors, suction pile anchors, piled anchors or combination anchors. Some oil companies today already have mooring systems designed for mooring in 1500m to 1800m of water and are contemplating designs for mooring in 3000m water depth.

Relative to present day offshore activities, newer vessels have become more complex and so have their mooring/anchoring systems. Under the prevailing sea conditions, a proper choice of anchors, clump weights, chains, and cables become vital for keeping a vessel on site and for the survival of the mooring system. There are two main issues driving the developments in deep water mooring and anchoring systems. The first is concerned with the weight of a conventional mooring system, which becomes significant as the water depth increases. This weight limitation has led to the development of synthetic fiber ropes, which are employed for deep water mooring systems. The synthetic fiber element is an alternative replacement to the steel cables and thus reduces weight and overall loads on the mooring lines.

The second issue is concerned with the radius of the mooring systems. For a conventional catenary mooring system, the radius is of the order of three times the water depth, for a deep water location over 1000m, the mooring radius will be very large and can significantly affect the subsea layout. This has consequently led to the development of the taut leg mooring systems, where the mooring radius is minimized by using an anchor, which can hold when subjected to some vertical loads.

The development solutions for ultra-deep water developments (3000m and beyond) is based on a combination of offshore technology incorporating marine operations, and floating production units like semi-submersible, Spar etc. The floating production units are kept in a place by an efficient mooring system.

Furthermore, there has been another development in terms of anchor weight versus vertical holding capacity. For instance, a vertical loading anchor (VLA) can withstand vertical loads up to 400times its own weight. One thing is the extremely low weight of the anchor (around 6 tons) and, still the extremely high holding capacity.

Furthermore the need for reliable and economic design of anchors for deepwater production units calls for a more detailed geotechnical investigation and advanced testing as compared to those done for less sizeable shallow water projects. An economic design of slender and suction piles anchors requires less variability in soil parameters. More advanced testing is required to derive design parameters relevant to issues such as soil set-up and long-term, cyclic and anisotropic strengths (Eltaher et al., 2003).

According to (Calverley, 2004),” Tried and tested steel cable products offer a mooring solution with long term experience and performance data. The suspended weight of steel mooring components presents a challenge as floating exploration and production facilities move into increasing water depth raising the issue of perceived limits for steel cables”.

It is apparent that the continued use of steel mooring line components remains possible with increasing water depth maintaining the confidence provided by proven technology. Nevertheless, continuing improvements in strength to weight ratio not only support the extension to useful depth range, but offer a more cost effective solution. Reductions in mooring system loads can be utilized through maximization of topside equipment. Fiber rope mooring systems offer the highest strength to weight ratio allowing exploration into ultra-deep locations. In order to protect the sensitive fiber product against wear, the use of steel is still apparent in taut systems. Note also that Spiral strand offers the most cost effective, weight conscious and technically advantageous solution to the connection between anchor and fiber rope (Calverley, 2004)

1.6 Dynamic Positioning (DP) Systems

An alternative to mooring systems is the Dynamic positioning system. Dynamic positioning (DP) systems which incorporate active heave compensation systems to achieve station keeping for safe and efficient marine operation activities could as well be used as an alternative to mooring/anchoring systems. Dynamic positioning is a technique of automatically maintaining the position of a floating vessel within a specified tolerance by controlling onboard thrusters which generate thrust vectors to counter the wind, wave and current forces. Dynamic positioning is particularly well suited for a vessel designed to arrive and leave location frequently, such as an extended well test system (API RP 2SK). It is also noteworthy to mention that many vessels designed to operate with moorings are also equipped with thrusters and thruster control systems. The thrusters can be used to control the vessel heading, reduce mooring load under severe environment, or increase the workability of the floating vessel.

1.7 Types of Anchors

Vryhof Anchors, one of the pioneer anchor manufacturers has classified anchors into various categories. A brief description of the different types of anchors as classified by Vryhof anchors is presented below.

1.7.1 Dead weight anchors

The dead weight anchors stands as one of the oldest anchors. The holding capacity is achieved by the weight of the material used in fabricating the anchor and partly by the friction between the dead weight and the seabed. Steel and concrete are common materials used today for manufacturing dead weight anchors. Consequently deadweight anchors are used on hard surfaces where penetration is difficult by

other types of anchors, for example in rock, gravel or coarse sand. An advantage of a deadweight anchor is that when dragged, it continues to provide its original holding force (Vryhof Anchors, 2010).
Dead weight anchors can also be used to provide protection for roof top workers. A schematic of a dead weight anchor is shown in Fig 1.1 below.

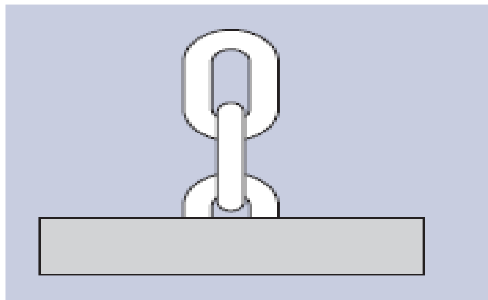

Fig 1.1: Dead weight anchor (Source Vryhof Anchors)

1.7.2 Drag embedment anchors

This is the most popular type of anchors available today. The drag embedment anchor has been designed to penetrate into the seabed, either partly of fully. The holding capacity of the drag embedment anchor is generated by the resistance of the soil in front of the anchor. The drag embedment anchor is very well suited for resisting large horizontal loads, but not for large vertical loads. Drag embedment anchors are used alongside catenary mooring on Semi-submersible and FPSO's. Drag embedment anchors are used on semi-submersible, SPM buoys and floating production units. Drag embedment anchors are also used to support floating wind turbines (Vryhof Anchors, 2010). An example of a Drag embedment anchor is shown in Fig 1.2 below.

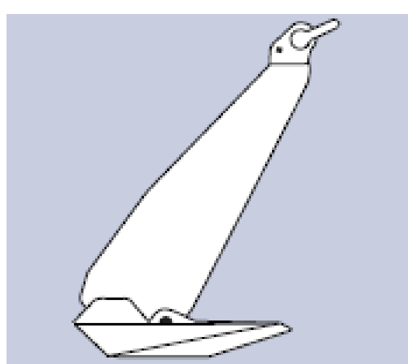

Fig 1.2: Drag embedment anchor (Source: Vryhof anchors)

1.7.3 Piles and gravitation anchors

Pile anchors are generally hollow steel pipes that are driven into the seafloor by means of a piling hammer or vibrator. The holding capacity of the pile is generated by the friction of the soil along the pile and lateral soil resistance. Generally the pile has to be installed at great depth below seabed to obtain the required holding capacity (Vryhof Anchor Manual, 2010). The pile anchors have capabilities of resisting both horizontal and vertical loads. An example of a pile anchor is shown in Fig 1.3 below.

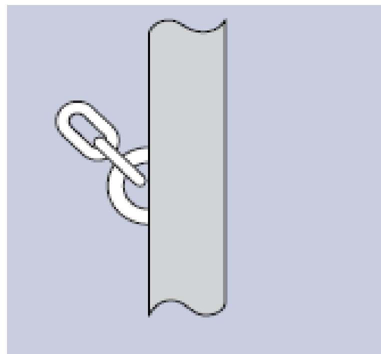

Fig 1.3 Pile anchor (Source Vryhof Anchors)

1.7.4 Suction anchors

The suction anchor is also a hollow steel pipe like the pile, although the diameter of the pipe is much larger than that of the pile. The suction anchor is forced into the seabed by means of a pump connected to the top of the pipe, creating a pressure difference. When the internal pressure of the pipe is lower than the external pressure, the pipe is sucked into the seabed. After installation the pump is removed. The holding capacity of the suction anchor is generated by the friction of the soil along the suction anchor and lateral soil resistance, also by the pressure inside the pile provided by the suction. The suction anchor is capable of withstanding both horizontal and vertical loads (Vryhof anchors, 2010). A schematic sketch of suction anchor is shown below in Fig 1.4.

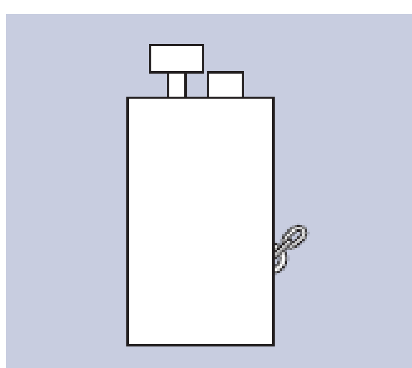

Fig 1.4: Suction anchor (Source: Vryhof Anchors)

1.7.5 Vertical Load Anchors (VLA)

The vertical load anchor is installed like a conventional drag embedment anchor, but penetrates much deeper. When the anchor mode is changed from the installation mode to the vertical (normal) loading mode, the anchor can withstand both horizontal and vertical loads. VLA’s are use with taut leg mooring systems (Vryhof Anchors, 2010). A vertical load anchor is shown in Fig 1.5 below.

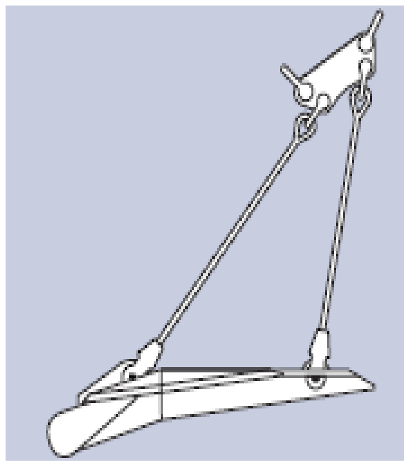

Fig 1.5: Vertical load anchor (Source: Vryhof Anchors)

1.8 Anchor Selection

There are various factors influencing the choice of selection of anchors. The selection of anchor type is dependent on the size of vessel, seabed layout, water depth, operational constraint, seabed slope, mooring leg configuration, type of vessel, soil condition, price, etc. The present day need for offshore operations that involves the deployment of moored vessels stationed in deep waters and subjected to harsh environmental conditions has made selection of mooring/anchoring system an important topic.

According to (Vryhof Anchors, 2010), the holding capacity of an anchor is a function of the following parameters:

- The fluke area, which is limited by the strength of the anchor design.
- The penetration depth of the anchor.
- The strength and weight of the soil.

The penetration of the anchor is governed by the soil type (deep penetration in very soft clay and shallow penetration in sand and hard clay), the anchor type (design), the type of mooring line that is used (chain or wire rope) and the applied load. An increase in fluke area or an increase in the penetration depth of the anchor results in a higher holding capacity.

1.9 Mooring systems

Mooring systems have been in existence as long as man has felt the need for anchoring a vessel at sea. These systems were used, and are still used, on ships and consisted of one or more lines connected to the bow or stern of the ship. Generally the ships stayed moored for a short duration of time (days).

When the exploration and production of oil and gas started offshore, a need for more permanent mooring systems became necessary. Different types of mooring systems have been developed over the years, some of which are presented below.

1.9.1 Basic Principles of mooring systems

Environmental forces on the drilling vessel are counterbalanced by the restoring forces which are supplied by tensions in the mooring lines. In turn, the mooring line tensions are transmitted to anchors on the ocean bottom. In order to gain a physical understanding of the spread mooring systems, it is necessary to consider the basic principles which govern the behavior of anchors and mooring lines.

1.9.2 Semi-submersible drilling rig mooring

Semi-submersibles platforms are moored using eight point lines. Usually, two mooring lines come together at each of the columns of the semi-submersible platform.

1.9.3 Catenary Anchor Length Mooring (CALM) buoy

In CALM systems, the buoy will be moored using four or more mooring lines at equally spaced angles. The mooring lines generally have a catenary shape. The vessel connects to the buoy with a single line and is free to weathervane around the buoy.

1.9.4 Single Anchor Length Mooring (SALM) buoy

These types of buoys have a mooring that consists of a single mooring line attached to an anchor point on the seabed, underneath the buoy. The anchor point may be gravity based or piled.

1.9.5 Turret mooring

This type of mooring is generally used on FPSOs and FSOs in more harsh environments. Multiple mooring lines are used, which come together at the turntable built into the FPSO or FSO. The FPSO or FSO is able to rotate around the turret to obtain an optimal orientation relative to the prevailing weather conditions.

1.9.6 Spread mooring

This is generally used on FPSOs and FSOs in milder environments. The mooring lines are directly connected to the FPSO or FSO at both the stern and bow of the vessel.

1.9.7 Selection of mooring systems

When oil and gas exploration and production was conducted in shallow to deep water, the most common mooring line configuration was the catenary mooring line consisting of chain or wire rope. For exploration and production in deep to ultra-deep water, the weight of the mooring line starts to become a limiting factor in the design of the floater. To overcome this problem, new solutions were developed consisting of synthetic ropes in the mooring line (less weight) and/or a taut leg mooring system.

The major difference between a catenary mooring and a taut leg mooring is that where the catenary mooring arrives at the seabed horizontally, the taut leg mooring arrives at the seabed at an angle. This means that in a taut leg mooring the anchor point has to be capable of resisting both horizontal and vertical forces, while in a catenary mooring the anchor point is only subjected to horizontal forces. In a catenary mooring, most of the restoring forces are generated by the weight of the mooring line. In a taut leg mooring, the restoring forces are generated by the elasticity of the mooring line.

An advantage of a taut leg mooring over the catenary mooring is that the footprint of the taut leg mooring is smaller than the footprint of the catenary mooring, i.e. the mooring radius of the taut leg mooring will be smaller than the mooring radius of a catenary mooring for a similar application. (Vryhof Anchors, 2010)

1.10 Mooring components

A typical mooring system can be divided in three different components, the mooring line, the connectors and the anchor point. A discussion on anchor points is done in **section 1.6.** (Types of anchors)

1.10.1 Mooring lines

Different materials are used as mooring lines. Some of them are briefly discussed below.

1.10.1.1 Chain

The most common product used for mooring lines is chain which is available in different diameters and grades. Two different designs of chain are used frequently, studlink and studless chain. The studlink chain is most commonly used for moorings that have to be reset numerous times during their lifetime, for instance semi-submersibles, while studless link chain is often used for permanent moorings (FPSOs, buoys, FSOs). A chain mooring line can be terminated in either a common link or an end link.

1.10.1.2 Wire rope

When compared to chain, wire rope has a lower weight than chain, for the same breaking load and a higher elasticity. Common wire ropes used in offshore mooring lines are six strand and spiral strand. The wire rope is terminated with a socket (for instance open spelter lines, closed spelter) for connection to the other components in the mooring system. Generally wire rope is more prone to damage and corrosion than chain.

1.10.1.3 Synthetic fiber rope

A recent development is the use of synthetic fiber ropes as mooring line. Typical materials that can be used are polyester and high modulus polyethylene. The major advantage of synthetic fiber ropes is the light weight of the material and the high elasticity. The synthetic fiber rope is generally terminated with a special spool and shackle for connection to the other components in the mooring system.

1.10.2 Mooring Connectors

1.10.2.1 Shackles

The shackle is a connector that is very common in the offshore industry. It consists of a bow, which is closed by a pin. Many different types of shackles are available, depending on the application. The shackle can be used in both temporary and permanent moorings. Example of shackles is shown in Fig. i.6 below.

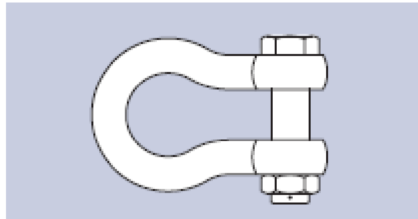

Fig. 1.6: Shackles (Source: Vryhof Anchors)

1.10.2.2 Connecting link kenter type

The connecting link kenter type is most commonly used for the connection of two pieces of chain mooring line, where the terminations of the two pieces have the same dimensions. The connecting link kenter type has the same outside length as a chain link of the same diameter. Generally connecting links kenter types are not used in permanent mooring systems, as they have a shorter fatigue life than the chain (Vryhof Anchors, 2010). An example is shown below.

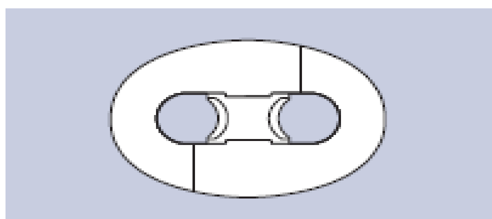

Fig 1.7: Connecting link kenter type (Source: Vryhof Anchors)

1.10.2.3 Connecting link pear shaped

The pear shaped connecting link is similar to the connecting link kenter type, except that it is used for the connection of two pieces of mooring line with terminations that have different dimensions. Like the connecting link kenter type, the pear shaped connecting links are not used in permanent mooring systems (Vryhof Anchors, 2010). An example is shown in Fig. 1.8 below.

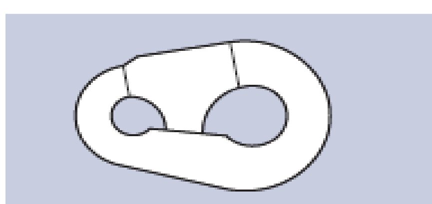

Fig 1.8: Connecting link pear shaped (Source: Vryhof Anchors)

1.10.2.4 Connecting link c type

Like the connecting link kenter type, the connecting link c type is used for the connection of two pieces of mooring line with terminations that have the same dimensions. The major difference between the kenter type and the c type is the way that the connector is opened and closed. This connector is generally not used in permanent moorings. An example is shown below in Fig. 1.9

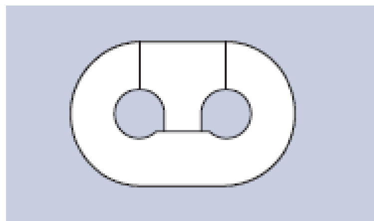

Fig 1.9: Connecting link C type (Source: Vryhof Anchors)

1.10.2.5 Swivels

A swivel is used in a mooring system, generally of a temporary type, to relieve the twist and torque that builds up in the mooring line. The swivel is often placed a few links from the anchor point, although it can also be placed between a section of chain and a section of wire rope. There are many different types of swivels available, although a disadvantage of most common swivels is that they may not function while under load, which is caused by high friction inside the turning mechanism. A new development is swivels that are capable of swiveling under load, due to special bearing surfaces inside the mechanism (Vryhof Anchors, 2010). An example of a swivel is shown in Fig. 1.10 below.

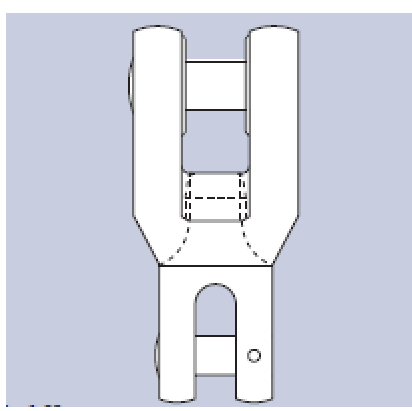

Fig .1.10: Swivel (Source: Vryhof Anchors)

1.10.2.6 Winches

Winches are used to handle and store wire rope. Dual drum winches are most common; however, single drum and quadruple drum units have been used. The size of a winch depends on the amount of wire rope to be stored on the drum and the maximum line pull to be exerted. A winch should be able to pull half the breaking strength of a mooring line, and should be equipped with mechanical brakes which can hold full breaking strength. Anchor winches on a drilling rig are usually driven by direct current (DC) electrical motors which are powered by the rig engines (Vryhof Anchors, 2010).

1.11 Selection of mooring components

Mooring line components includes metallic and non metallic ropes chains, links and connecting hardware. They come in all types, materials and sizes, and, consequently, their choice, which is a function of the application, life expectancy, and the restraints involved, can be cumbersome.

Water depth is a demanding requirement for mooring, and often trade-offs must be made between cost, ease of operation, and weight. The types of components that can be used are decided by environmental conditions and operational factors. For instance, in areas where biological attacks are probable, the use of fiber ropes is not feasible. Design criteria for mooring line components are also based on factors such as vessel size, environmental loads, operational constraints, availability of the line hardware, and safety.

CHAPTER TWO

Analysis of Mooring and Anchoring Systems

2.0 Overview of mooring/anchoring systems

The analysis of mooring and anchoring systems from an application point of view is presented in this chapter. A detailed description of the types of anchors and mooring systems is also presented. Furthermore, SWOT (Strength, Weakness, Opportunities and Threat) analysis of various anchors and mooring systems is also carried out. Aspect of soil mechanics in anchor design is furthermore discussed in this chapter.

2.1 Historical background of mooring systems

Today, interest in anchor development has been revived by the floating drilling industry, whose offshore operations require anchors with improved holding power in all types of bottom conditions, including both mud and sand.

As anchors have improved over the years, so did mooring lines. Natural fiber rope is seldom used alone in modern mooring applications in view of its light weight, low breaking strength, and susceptibility to biological attack. With light weight and low breaking strength, fiber rope is prone to jerk in taut mooring systems and break in severe weather conditions. By comparison, a metal chain has much greater weight and a higher breaking strength. The advantage of a chain mooring line is that it forms a catenary curve, a “spring” which will absorb shock of surge loadings and bring a vessel under control without shock damage in adverse weather conditions (Dailey, 1976).

Furthermore, Wire rope has evolved over the years; it represents a combination of modern steel technology with ancient rope-making traditions. In comparison with chain, wire rope has a much greater strength-to weight ratio, but is much more susceptible to damage by abrasion, corrosion and general abuse. In mooring applications where technical feasible, chain is usually favoured over wire rope. However, wire rope is used extensively in deep water mooring systems where high strength-to weight ratio is important. Composite mooring systems, including both wire rope and chains combine the advantage of both and dispel their disadvantages.

It is important that the mooring system for a floating vessel or MODU is fit for the purpose it is designed for. The mooring system comprises freely hanging lines connecting the surface platform to anchors on the sea bed, positioned at some distance from the platform. Steel-linked chain and wire rope have conventionally been used for mooring floating platforms. The mooring lines are laid out, often symmetrically in the plan view, around the vessel. Each of the lines forms a catenary shape which depends on an increase/decrease in line tension as it lifts off or settles in the sea bed, to produce a restoring force as the surface platform is displayed by the environment (Chakrabarti, 2005).

With the requirement to operate in increasing water depths, the suspended weight of mooring lines becomes a prohibitive factor. In particular, steel chains become less attractive at great water depths. Recently, advances in taut synthetic fiber rope technology have been achieved offering alternatives for deep water mooring. Mooring systems using taut fiber ropes have been designed and installed to reduce mooring line length, mean-and low-frequency platform offsets, fairlead tension, and thus total mooring cost. To date however, limited experience has been gained in their extended use offshore when compared to traditional catenary moorings.

Functional requirements of mooring systems

The functional requirements a mooring system must satisfy includes but not limited to the following:

- Installability
- Position ability
- Station keeping capabilities
- Lifetime before replacement
- Offset limitations

These requirements are determined by the function of the floating vessel. MODU are held to less restrictive standards than “permanent” mooring systems of production platforms (Chakrabarti, 2005). The basic differences are presented in Table 2.1 below.

Table 2.1: Comparison of typical MODU and FPS floating requirements

MODU	Floating Production platform
Design for 50-yr return period event. Anchors may fail in larger events.	Design for 100-yr return period events
Risers disconnected in the storm	Risers remain connected in storm
Slack moorings in storm events to reduce line tension.	Moorings are usually not slacked because of risk to risers, and lack of marine operators on board.
Components designed for less than 10 year life	Components designed for greater than 10 year life
Fatigue analysis not required	Fatigue analysis required
Line dynamic analysis not required	Line dynamic analysis required
Missing line load case not required	Missing line load case required

(Source: Chakrabarti, 2005)

2.2 Factors determining Selection of mooring system

Mooring line components includes metallic and non-metallic ropes, chains, links and connecting hardware. They come in all types, materials and sizes, and, consequently, their choice, which is a function of the application, life expectancy, and the restraints involved, can be cumbersome.

Water depth is a demanding requirement for mooring, and often trade-offs must be made between cost, ease of operation, and weight. The types of components that can be used are decided by environmental conditions and operational factors. For instance, in areas where biological attacks are probable, the use of fiber ropes is not feasible. Design criteria for mooring line components are also based on factors such as vessel size, environmental loads, operational constraints, availability of the line hardware, and safety.

The main components of a mooring system may consist of

- Chain, wire or rope or their combination
- Anchor or piles
- Fairleads, bending shoes or pad eyes
- Winches, chain jacks or windlasses
- Power supplies
- Rigging(e.g. stoppers, blocks, shackles)

2.3 Wire ropes

Ropes made of metallic wires are used extensively as mooring lines. Wire ropes consist of individual wires wound in a helical pattern to form a "strand". The pitch of the helix determines the flexibility and axial stiffness of the strand. The wire ropes used for mooring can be multi-strand or single strand construction. These ropes have excellent strength to size ratio but poor strength to weight ratio. They are easy to handle and they have relatively low cost. However, they are susceptible to fatigue, corrosion and kinks. Often, metallic ropes are covered by a water proof jacket of hard plastic, such as polyethylene, thus providing protection against corrosion and abrasion. Most wire ropes are made of carbon steel, but stainless steel and other alloys are also becoming popular in deep water applications, because of their higher breaking stress and corrosion resistance qualities. Because a higher strength to weight ratio is a desirable characteristic for a mooring line, ropes made of higher strength steels are generally preferred. An example of Wire rope is shown in Fig. 2.1.

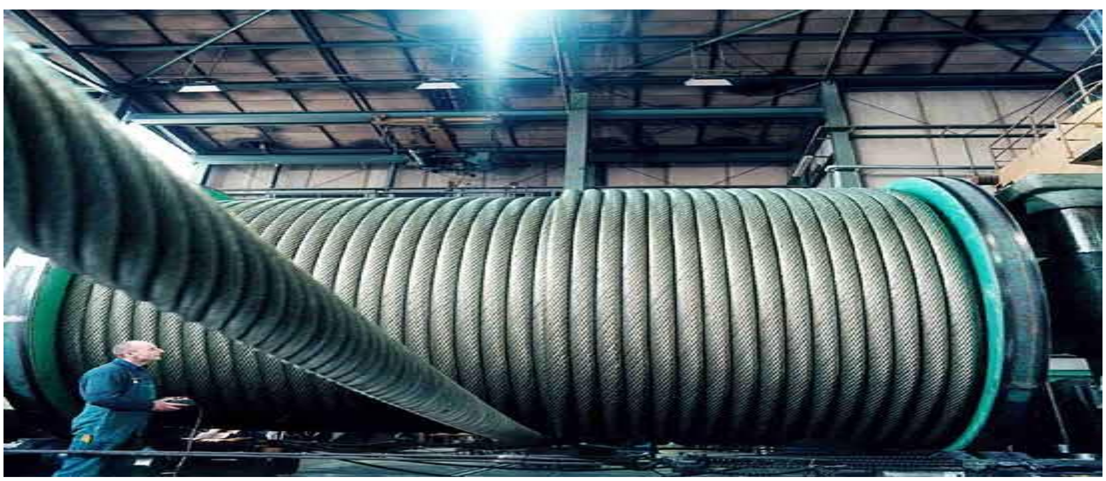

Fig 2.1: Metallic wire ropes (Source: Offshoretechnology.com)

Metallic ropes offer a definite advantage in that they have little ductility and thus elongation is small and occurs only at high tension. The main disadvantages associated with metallic ropes are their weight and short life expectancy. Furthermore, too many mooring legs may be required with metallic wire rope in deep water applications. SWOT Analysis is shown in Table 2.2 below.

Table 2.2: SWOT Analysis of Wire ropes

STRENGTH	WEAKNESS
• Excellent strength-to-size ratio • Easy to handle • Low cost • Not susceptible to fish bite • Little ductility gives small elongation	• Too many ropes required • Poor strength –to-weight ratio • Short life expectancy
OPPORTUNITIES	**THREATS**
• When wire ropes are covered with water proof jacket or hard plastics, it can provide protection against corrosion and abrasion	• Susceptible to fatigue • Susceptible to corrosion • Susceptible to kinks

2.4 Synthetic fiber ropes

Ropes constructed of Nylon, Dacron, Kevlar, polypropylene, polyethylene, etc. are often used as mooring line components. These ropes do not corrode or deteriorate appreciably in sea water. Their strength to immersed weight is excellent and they are quite easy to handle. However, they are susceptible to fish bites and consequently the use of small size fiber ropes in deep waters where fish attacks are likely to occur has often resulted in mooring losses. At high stress, plastic flow of the fiber can occur resulting in premature failure. Because of the low allowable load per leg, an excessive number of mooring legs may be required with fiber ropes (Vryhof Anchors, 2010).

For deep water applications, synthetic fiber lines can have significant advantages over a catenary chain or wire because they are considerably lighter, very flexible and can absorb imposed dynamic motions through extension without causing an excessive dynamic tension. Additional advantages include the fact that there is reduced line length and sea bed footprint. The disadvantages in using synthetics are that their material and mechanical properties are more complex and not as well understood as the traditional rope. This often leads to over-conservative designs that strip them of some of their advantages. Furthermore, there is little in service experience of these lines. An example of synthetic fiber rope is shown in Fig.2.2.

Fig 2.2: Synthetic fiber ropes (Source: offshoremoorings.org)

Furthermore, The SWOT Analysis of synthetic fiber rope is shown in Table 2.3 below.

Table 2.3 SWOT Analysis of Fiber ropes

STRENGTH	**WEAKNESS**
• Flexibility • Ease of handling • High strength-to –weight ratio • Suitable for deep water applications	• Susceptible to fish bite • Complex material and mechanical properties • Higher factor of safety required • Excessive number of mooring legs required
OPPORTUNITIES	**THREATS**
• The stretching of the rope could be used as an advantage in rough weather conditions.	• Plastic flow of the fiber can occur which will consequently lead to premature failure • Could result to mooring looses in case of fish bite

2.5 Chains

Chain and wire make up the strength members of the mooring system. There are two primary chain constructions, stud-link chain and studless chain. Stud-link chain is often used for MODU and FPSOs mooring in relatively shallow water. The studs provide stability to the link and facilitate the laying of the chain while handling.

Conversely, studless chains are used nowadays for permanent moorings. Eliminating the stud reduces the weight per unit strength and increases the chain fatigue life, at the expense of making the chain less convenient to handle (Chakrabarti, 2003). Example of stud-link chain and studless chain is shown in Fig. 2.3 below. With increase in water depth, chains become less feasible because of the weight, cost and high loads they impose on the vessel. As a result, mooring systems for deep water applications often use lighter components. At times, where necessary, chain lengths are inserted in deep water mooring lines to provide higher strength and abrasion resistance. Furthermore, because of its weight, a length of chain attached to an anchor will reduce the vertical pull on the anchor. The biggest advantage with chains is that larger catenary allows more lateral vessel excursion. Other advantages are their long life span and high strength.

Table 2.4 SWOT Analysis for Chains

STRENGTH	WEAKNESS
• Suitable in shallow waters • High strength • Larger catenary is achieved allowing lateral vessel excursions	• Not suitable for deep water applications because of the weight • High cost
OPPORTUNITIES	**THREATS**
• It can be inserted in the mooring line at the bottom of fiber ropes on the sea floor to provide higher strength and abrasion resistance which will eventually reduce the vertical pull of the anchors	• Imposes high loads on vessels therefore it is not suitable for deep water applications.

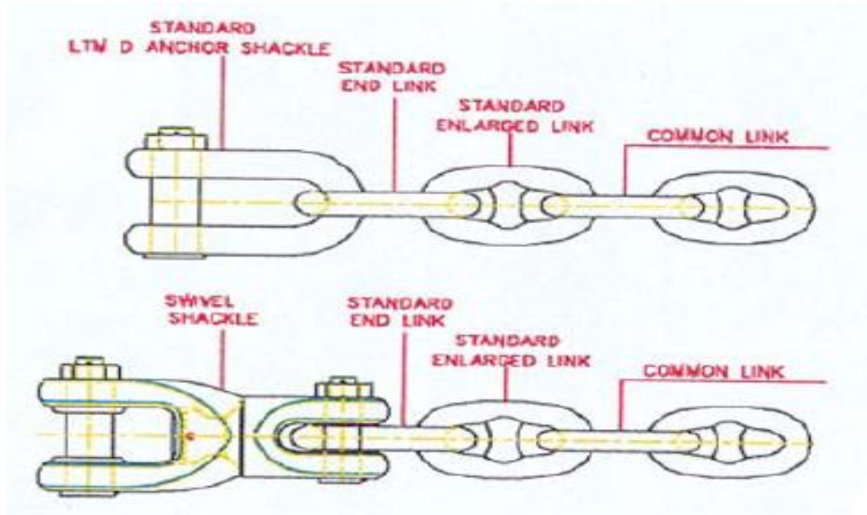

Fig 2.3.1: Standard studlink chain and accessories (Source: DNV RP E301)

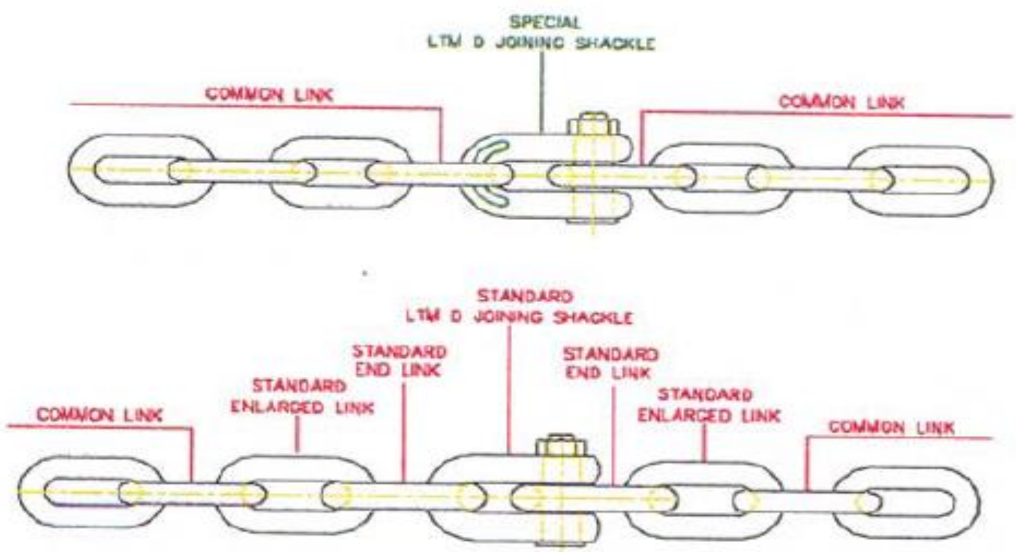

Fig 2.3.2: Standard studless chain and accessories (Source: DNV RP E301)

2.6 Classification of Anchors

A further classification of anchors is given by Vryhof Anchors is presented below. The criteria for classification include: fluke area, shank, and stabilizers. To allow a rough comparison of anchor type efficiency, an indication (*) is provided for a 10 tonnes anchor as (HOLDING CAPACITY = **WEIGHT * EFFICIENCY**).

Hence the anchor efficiency is defined as the holding capacity divided by the weight. The holding capacity comprises both vertical and horizontal holding capacity. Holding power of an anchor is often expressed in term s of a ¨holding power ratio¨, which is defined as the mooring line tension on the anchor divided by the weight of the anchor in air. An efficient anchor should have high holding power ratio; that is it should develop a maximum of holding power for a minimum weight. Ideally, the holding power ratio for a given anchor should exceed10 for all types of bottom conditions ranging from hard sand and clay through soft mud. A more conservative rule of thumb is that holding power may be estimated as three times anchor weight (Vryhof Anchors, 2010).

R. W. Beck (1972) confirmed that maximum holding power is sensitive to fluke angle setting. For a soft bottom, the fluke angle should be set at about 50^0. Where the bottom is hard, the fluke angle should be closed down to approximately 30^0. M. A. Childers (1972) also notes that holding power has been improved in hard bottom areas by sharpening the fluke edges with a cutting torch and increasing the length of the stock. This prevents the anchor from turning over and gives the fluke’s better designing power. There are six classes of anchors according to Vryhof, 2010; Classes A to F. The different classes with pictures are presented below.

Class A: The efficiency range is from *33 to 55. These are slender anchors with ultra-penetration. Examples are shown in Fig. 2.4.1 below.

Fig 2.4.1: Class A Anchors (Source: Vryhof Anchors)

Class B: The efficiency range for these anchors is from *17 to 25. These are anchors with 'elbowed' shank, thus, allowing for improved penetration. Examples are shown in Fig 2.2 below.

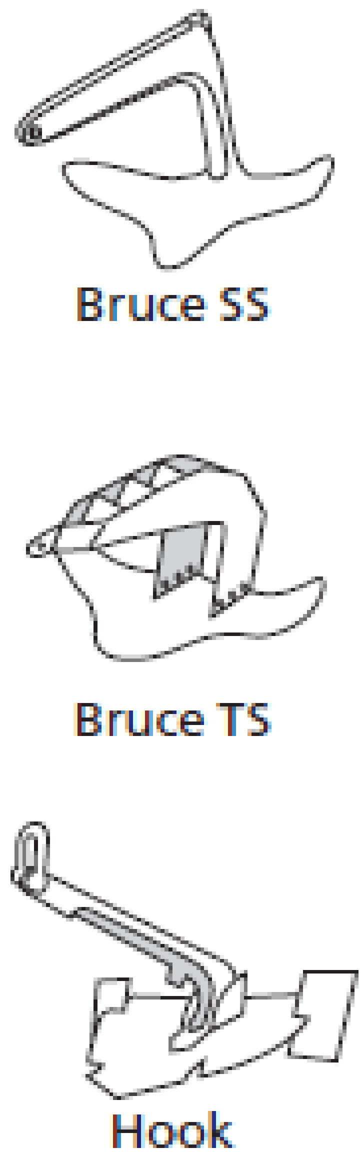

Fig 2.4.2 : Class B Anchors (Source: Vryhof Anchors)

Class C: The efficiency range of these anchors is from *14 to 26. These are anchors with open crown hinge near the centre of gravity and relatively short shank and stabilizers or built-in stabilizers. Examples are shown in Fig 2.3 below.

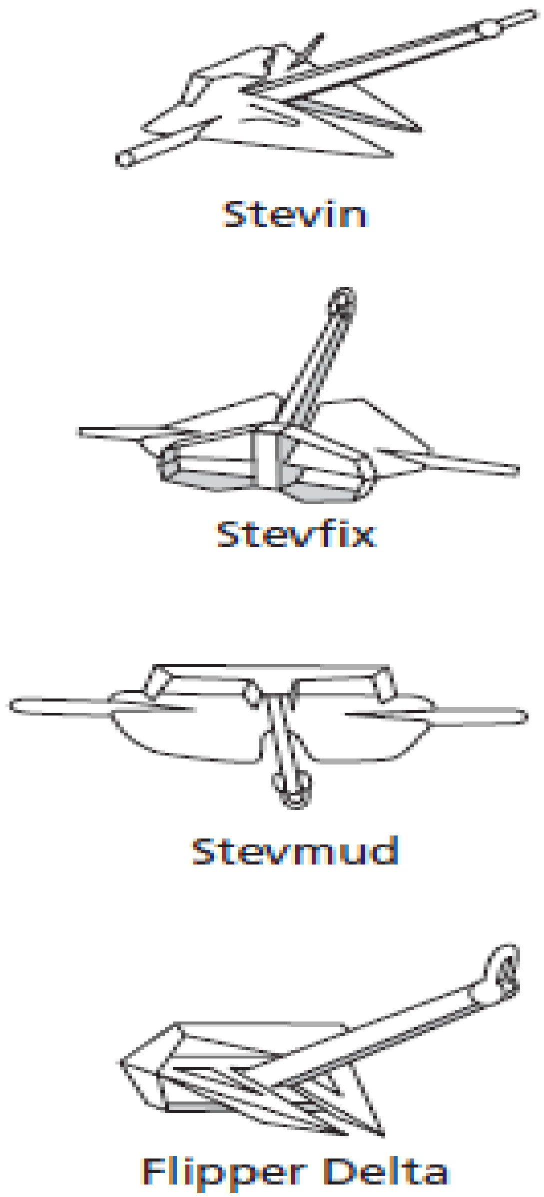

Fig 2.4.3: Class C Anchors (Source: Vryhof Anchors)

Class D The efficiency of these anchors ranges from *8 to 15. These are anchors with hinge and stabilizers at the rear and relatively long shanks and stabilizers. Examples are shown in Fig 2.4 below.

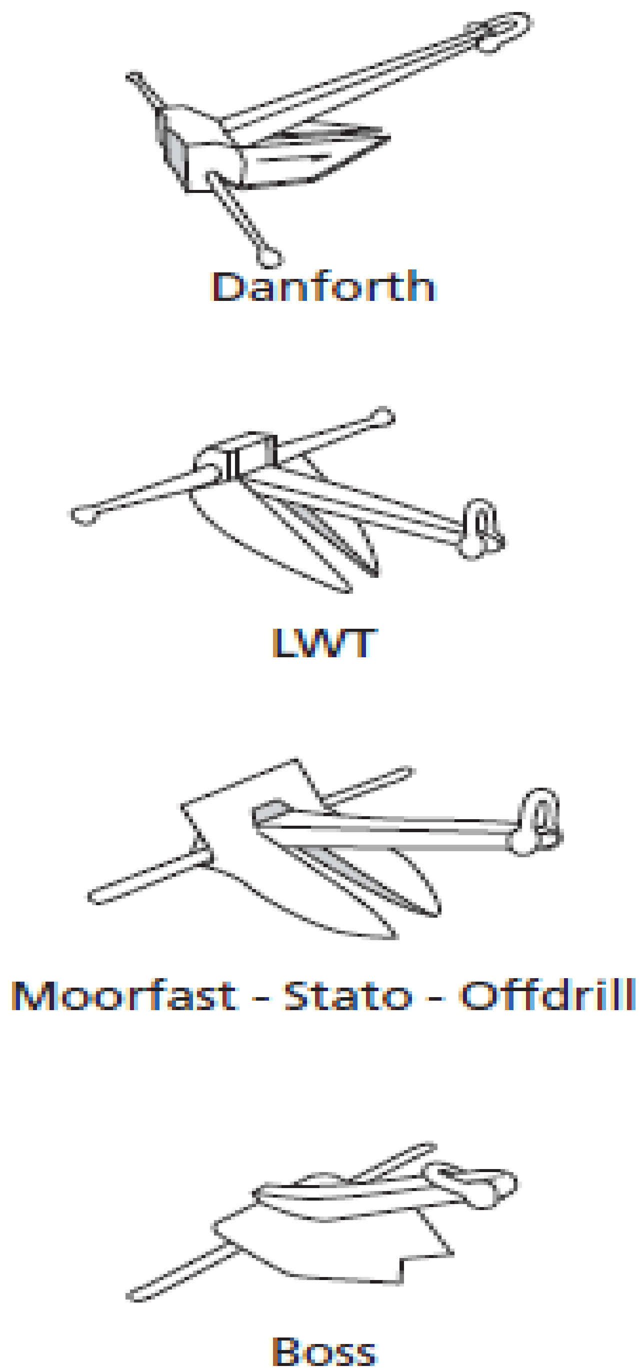

Fig 2.4.4: Class D Anchors (Source: Vryhof Anchors)

Class E: The efficiency range is from *8 to 11. These are anchors with very short, thick stabilizers; hinge at the rear and a relatively short, more or less square-shaped shank. Examples are shown in fig 2.5 below.

Fig 2.4.5: Class E Anchors (Source: Vryhof Anchors)

Class F: The efficiency range is from *4 to 6. These are anchors with square shank, no stock stabilizers. The stabilizing resistance is built-in the crown. Examples of anchors in this category are shown below in Fig 2.6.

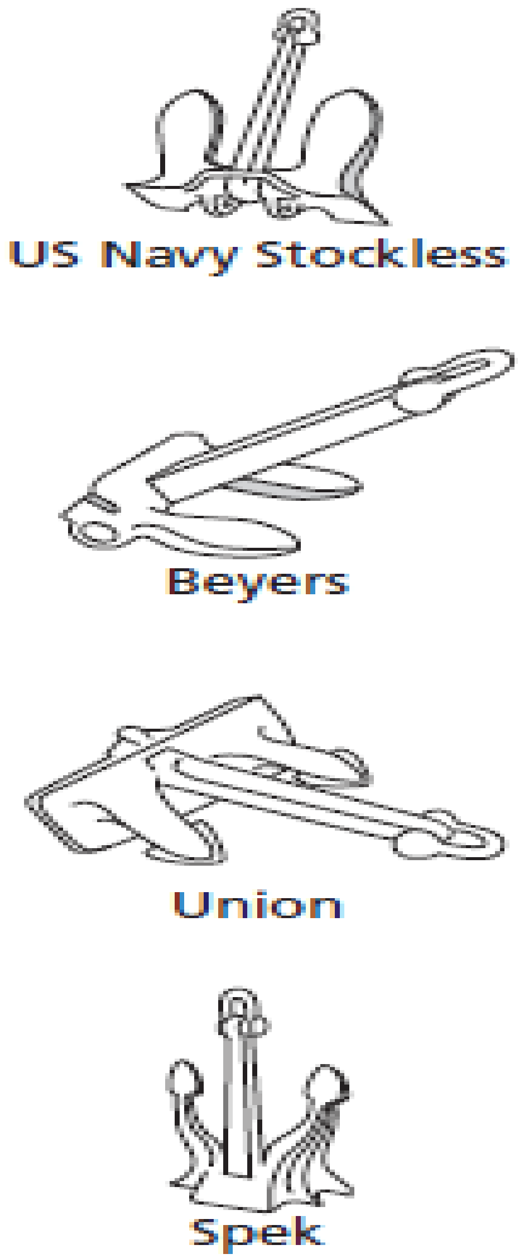

Fig 2.4.6: Class F Anchors (Source: Vryhof Anchors)

2.7 Performance of Anchors

The performance of an anchor is influenced by many different parameters, some of which are: fluke area, shank design, soil conditions, load conditions, type of mooring line. This section discusses how these parameters influence the performance of the anchor. There are several attributes of an anchor which are crucial in assuring its effective performance. Some of the attributes are enumerated below.

a) The anchor must offer a high holding capacity; a result of the fluke area and shank design in combination with penetration and soil type.
b) The anchor should be streamlined for low penetration resistance.
c) The design of the anchor should be such that the anchor is capable of being used successfully in practically all soil conditions encountered over the world, ranging from very soft clay to sand and corals
d) The fluke/shank angle of the anchor should be easily adjustable, allowing the anchor to be quickly deployed in different soil conditions.
e) The design must be so conceived and produced that the high loads common in practice can be resisted and that the anchor can be easily handled, installed, retrieved and stored.
f) The penetration of an anchor depends upon its shape and design. Obstructing parts on the anchor should be avoided as much as possible.
g) The stability of an anchor encourages its penetration and, consequently, it’s holding capacity. Efficient stabilizers are an integral part of a good anchor design.
h) The shank must permit passage of the soil.
i) The surface area of an anchor fluke is limited by the required structural strength of the anchor.
j) The anchor design must have optimal mechanical strength to fulfill requirements and stipulations of the classification societies.
k) The anchor should be designed to ensure an optimum between structural strength of the anchor and holding capacity.

(Vryhof Anchors, 2010)

2.8 How Soil Conditions affect Anchor design and installation

The penetration of the anchor is governed by the soil type (deep penetration in very soft clay and shallow penetration in sand), the anchor type (design), the type of mooring line that is used (chain or wire rope) and the applied load. An increase in fluke area or an increase in the penetration depth of the anchor results in a higher holding capacity.

It is important to have a comprehensive understanding of the soil characteristics and behavior in anchor design process. It is important to carry out geotechnical investigations of the soil properties before deciding the type of anchoring system to use for a marine operations project. Geophysical/geo-hazards investigation is also necessary. These are used mainly to get an idea of geologic features, identify geo-hazards at the project site as well as to establish the uniformity (or the lack thereof) of soil formation.

(Eltaher et al, 2003), states that “Soil properties obtained from deepwater geotechnical investigation usually include stratigraphy, type and consistency; unit weight; stress history; static and cyclic, anisotropic, undrained, undisturbed and remolded shear strength profiles; and hydraulic conductivity and consolidation properties. Anisotropic and cyclic soil strength properties, derived from consolidated triaxial and DSS testing are especially required for the design of slender anchor piles and suction piles. Soil response to cyclic loading should be investigated under different cyclic/average load ratios, based on the actual loads”. Soil conditions influences anchor design in a lot of ways. Some of which are explained below.

2.8.1 Anchor type

Some anchors are more suited for soft soil conditions (soft clay), while others are more suited for hard soils (sand and hard clays), although there are a number of anchor types on the market that are suited for most soil conditions encountered.

2.8.2 Holding capacity

In hard soil like sand and hard clay, the maximum attainable ultimate holding capacity with a certain anchor type and size is higher than the attainable ultimate holding capacity in very soft clay.

2.8.3 Penetration and drag

In very soft clay the anchor will penetrate deeper than in harder soil like sand. As a consequence, the drag length of the anchor and then the mooring line length will also be longer in very soft clay than in hard soil.

2.8.4 Retrieval forces

When an anchor is installed in very soft clay, the required retrieval forces will be higher than in hard soil like sand. For example, in very soft clay the required retrieval force of an anchor can be equal to 80%-90% of the installation load while in hard soil (sand) the retrieval force might only be 20%-30% of the installation load. Soil strength is generally expressed in terms of the shear strength parameters of the soil. The soil type is classified mainly by grain size distribution.

2.9 Behavior of Anchors in different soil conditions

Depending on the soil conditions, different loading situations can occur on the anchor. In sands and clays, the load tends to be spread equally over the anchor, which generally presents no problems. Retrieval is also very simple, without excessive loads placed on the anchor. In very hard soils, the anchor has to be able to withstand the load with only one or two of the fluke tips buried in the soil, as penetration in very hard soil conditions is generally shallow.

According to (Vryhof Anchors, 2010), in very soft clays (mud); penetration of the anchor is uncomplicated. However, recovery of the anchor can cause high loads, sometimes exceeding the load that was used to install the anchor. Sideward forces on the top of (shallow) buried anchors can be so extreme that no anchor is capable of resisting them.

Care should be taken during the handling of the anchors, as the loads exerted by the winches, vessels and chain can sometimes exceed the structural strength of the anchor and cause damage. Anchor designers attempt to design the anchors for these high loads; however this is not always possible due to variations in the magnitude of the loads during handling operations.

2.10 Design Modifications

The following design modifications have been incorporated in anchor design over the years to increase the efficiency of anchors in deep water applications.

2.10.1 Streamlining of the anchor

In order to achieve optimal penetration in the soil, it is important to streamline the anchor. Tests have shown that an anchor with protruding parts will encounter much more soil resistance and consequently will not penetrate as deep as a more streamlined anchor with the same fluke area.

2.10.2 Shank shape

A square shank, which is common for most of the older type single shank anchors, will cause penetration resistance due to the fact that the soil cannot pass easily past the shank. A clod of soil will form underneath the shank, effectively increasing the resistance of the soil. When the single shank is replaced by a twin shank construction (for instance Stevpris, FFTS), usually two thin parallel steel plates, and the soil can more easily pass through and past the shank, consequently, the twin shank anchor can penetrate deeper (Vryhof Anchors, 2010).

CHAPTER THREE

REGULATIONS AND STANDARDS

3.0 Overview

Regulations guiding the use of mooring and anchoring systems in different offshore environments are discussed in this chapter. These regulations deal with offshore standards, technical requirements and guidelines for the design, construction and installation of mooring/anchoring systems. The objective of these regulations is to give a uniform level of safety for mooring/anchoring systems. These regulations also serve as guideline for designers, contractors and buyers.

The recommended practices normally referred to for design of mooring systems are given in industry recommended practices by API RP 2SK, API (2005) and Det Norske Veritas (DNV RP E 301), DNV (2010). Authorities like Norwegian Petroleum Safety Authority (PSA, 2012) and Norwegian Maritime Directorate (NMD, 2012) provide the rules and requirements.

3.1 Industry standards and classification rules

Several standards, regulations and guidelines are provided for design of mooring systems for offshore vessels. Some of the standards and guidelines for design of mooring systems are listed below:

- API RP 2SK (American Petroleum Institute- Recommended Practice for Design and Analysis of Station-keeping Systems for Floating Structures)
- DNV-OS-E301 (Det Norske Veritas- Position Mooring)
- DNV-RP-C205 (Det Norske Veritas- Environmental Conditions and Environmental Loads)
- GL Noble Denton (Guidelines for Moorings)
- ISO 19901-7 (International Standard- Petroleum and natural gas industries – Specific requirements for offshore structures- Stationkeeping systems for floating offshore structures and mobile offshore units)

The standards listed above represents the guidelines and acceptable criteria for design of mooring systems for offshore applications. They were developed for design, analysis and evaluation of station-keeping systems used for various types of floating platforms. Station keeping is a term for controlling the floating structure against external actions, on a pre-defined location and/or heading with limited excursions (API RP 2SK). The external actions generally consist of environmental forces (wind, wave, and current) on the floating structures and mooring system. The guidelines and standard mainly concerned with spread mooring systems and single mooring systems which are comprises chain, wire rope and synthetic fiber ropes. ISO 19901-7 is an extensive standard for design of all mooring systems for offshore applications. API Recommended Practice (API RP 2SK, 2005), includes some guidelines which are not included in the International Standard ISO 19901-7

In this thesis all criteria and coefficients are found according to DNV-OS-E301 and DNV-RPC205. DNV-OS-E301 offshore standard contains criteria, technical requirements and guidelines for design and construction of position mooring systems. The standard is appropriate for columns stabilized units, ship-shaped units, loading buoys and deep draught floaters (DDF) or other floating bodies with catenary mooring, semi-taut and taut leg mooring system. The aim of this standard is to give a uniform level of safety for mooring systems. Industry guidance notes or recommended practice are non-binding recommendations, which are normally incorporated into the design criteria either in whole or in part. The specific requirements for floating production systems vary among the various references. Authorities might refer to industry guidance documents.

There is a significant difference in the current recommended mooring criteria between the European (mainly North Sea) and those applied in the U.S Gulf of Mexico as reflected in DNV RP E 301 and API RP 2SK, respectively. As an example, the above mentioned DNV offshore standard for position mooring specifies different safety factors for design depending on the criticality of production. The safety factors are applied differently. DNV makes allowance for application of quantitative risk assessment methods for the selection of appropriate design load.

The safety factors for the computed mean mooring load as stipulated by DNV and API are shown in Table 3.1 below.

Table 3.1 Safety factors (FOS) for mooring loads

Position Mooring	**Load**	**FOS**
DNV RP E 301	Mean mooring load	1.4
	Dynamic load	2.1
API RP 2SK	Peak loads for all types of mooring systems	1.67

(Source: Chakrabarti, 2003)

A number of sea states should be selected along the "contour line" representing the joint probability of significant wave height and peak wave period combinations at the mooring location. In order to calculate the mooring line structural response, it is necessary to apply the appropriate environmental loads for the sea state under consideration. This usually corresponds to the wave and wind conditions having a return period of 100-year, together with 10-year return period current conditions.

The weather directions to be considered depend on the vessel mooring arrangement:

- For vessels that cannot change direction relative to the weather, it is necessary to consider waves, wind and current acting from several directions. These are head, quartering and beam seas, together along the mooring line for vessels with symmetric mooring patterns.
- For non-symmetric mooring patterns, environmental loading from all directions, with a maximum 45^0 spacing, should be assessed.
- For vessels that can weathervane, site data should be used, if available, otherwise collinear weather should be applied at 15^0 to the vessel bow, together with a non-collinear condition with bow waves, wind and current acting from the same side at respectively 30 and 45^0 to the bow.

Wind and current loads are usually established by model tests and/or calculations. Furthermore, marine growth on long-term moorings should be included by increasing the line weight and the drag coefficient C_d (Chakrabarti, 2005).

A marine growth density of 1325kg/m^3 is common, and the standards provide equations to calculate the mass of growth depending on the line type and diameter, together with growth thickness and water depth (Chakrabarti, 2005). The line drag coefficient can be assumed to increase linearly with growth thickness. Table 3.2 indicates the following drag coefficients for different mooring lines:

Table 3.2 Drag coefficient for mooring lines

Drag coefficient(C_d)	Mooring Line
2.6	Studlink chain
2.4	Studless chain
1.8	Six-strand wire rope
1.2	Spiral strand with sheathing
1.6	Spiral strand without sheathing

(Source: Chakrabarti, 2005)

3.2 Factors of Safety

API RP 2SK provides guidelines for the design and analysis of stationkeeping systems for floating structures. These guidelines state that the minimum Factors of Safety for intact and damaged conditions for the mooring lines are as follows:

Factor of Safety = Maximum Bending Load/Max Line Tension

- Intact conditions = 1.67
- Damage conditions (1-line broken) = 1.25

Mooring line safety factors are shown in Table 3.3 below for API RP 2SK which is based on principle of allowable loads.

Table 3.3: Mooring line Safety factors according to API

Mooring line safety factors	Quasi-static load	Dynamic load
Intact load condition	2.00	1.67
Damaged load condition	1.43	1.25
Transient load condition	1.18	1.05

(Source: API RP 2SK)

3.3 Safety factors for anchor design

For geotechnical design of anchors, the factor of safety is usually defined as the ratio of the ultimate holding capacity of the anchor to the maximum applied load. The factors of safety used by the industry for axial capacity of anchors in catenary and taut leg systems are around 2.0 and 1.5 for the 100-year design event, Intact and Damaged conditions, respectively (Eltaher et al, 2003) .

Though specified in a number of codes, the factor of safety for the lateral capacity of slender anchor piles hardly ever controls any aspect of the pile design.

With the fundamental behavioral differences between conventional drag anchors and Vertical Load Anchors (VLA), factors of safety have been increased for VLAs, relative to conventional drag anchors, as given in Table 3. 4. A higher factor of safety is required for VLA's. This is as a result of the difference in failure mode of the anchor. The drag embedment anchor is pulled horizontally through the soil and keeps the resistance. VLA is slowly pulled to the surface due to the vertical load component.

Table 3.4 summarizes factors of safety for anchor holding capacities.

Table 3.4: Safety factors for anchors holding capacity according to DNV

	Taut and Semi-Taut Leg Systems under 100-year storm	
	Intact	Damaged
Anchor Piles, Suction Piles, and VLAs	2.0	1.5

	Catenary Systems under 100-year storm	
	Intact	Damaged
Conventional Drag Anchors	1.5	1.0

(Source: DNV RP E 301)

Load and Resistance Factor Design (LRFD) method is currently gaining popularity, with its advantage of assigning partial factors to different contributors in a process and, to better model their different inherent uncertainties. However, more experience and studies are needed to isolate and identify the different factors for different applications.

Furthermore API RP 2SK gives the factor of safety for drag embedment anchors as shown in Table 3.5.

Table 3.5 Factor of Safety for Drag embedment anchors according to API

	Quasi-static FOS	**Dynamic FOS**
PERMANENT MOORING	F.O.S	F.O.S
Intact condition	1.8	1.5
Damaged condition	1.2	1.0
TEMPORARY MOORING		
Intact Condition	1.0	0.8

(Source: API RP 2SK)

From Table 3.5 above, we can see that the dynamic values are less than the static values. The Factor of safety for pile and suction anchors according to API are presented in Table 3.7 below.

Table 3.6 Factor of Safety for Pile and suction anchors according to API

Condition	Suction/Driven Pile and Gravity Anchor				Plate Anchor	
	Permanent		Mobile			
	Lateral	Axial	Lateral	Axial	Permanent	Mobile
Intact	1.6	2.0	1.2	1.5	2.0	1.5
Damaged	1.2	1.5	1.0	1.2	1.5	1.2

(Source: API RP 2SK)

3.4 Partial Safety Factors and premises

The mooring system shall be analyzed according to design criteria formulated in terms of three limit state equations:

a) An Ultimate Limit State (ULS) to ensure that the individual mooring lines have adequate strength to withstand the load effects imposed by extreme environmental actions.

b) An Accidental Limit State (ALS) to ensure that the mooring system has adequate capacity to withstand the failure of one mooring line, failure of one thruster or one failure in the thrusters' control or power systems for unknown reasons. A single failure in the control or power systems may cause that several thrusters are not working.

c) A Fatigue Limit State (FLS) to ensure that the individual mooring lines have adequate capacity to withstand cyclic loading.

FLS is mainly of concern for steel components where fatigue endurance may be limiting the design. For fiber-rope segments, the time-dependent strength may be limiting the design, thus stress rupture or creep failure should be incorporated in the checks for ULS and ALS as appropriate (DNV, 2010).

Consequence classes

Two consequence classes are introduced in the ULS and ALS, defined as:

Class 1

Where mooring system failure is unlikely to lead to unacceptable consequences such as loss of life, collision with an adjacent platform, uncontrolled outflow of oil or gas, capsize or sinking.

Class 2

Where mooring system failure may well lead to unacceptable consequences of these types. The partial safety factors given in Table 3.5 below are applicable to chain, steel wire ropes and synthetic fiber ropes.

If the characteristic mean tension exceeds 2/3 of the characteristic dynamic tension, when applying a dynamic analysis in consequence class 1, then a common value of 1.3 shall be applied instead of the separate static and dynamic safety factors given in Table 3.8. This is intended to ensure adequate safety in cases the tension is dominated by the mean tension component.

For several types of single point mooring systems the system is designed without redundancy and consequently ALS is not an applicable design condition. These systems may be accepted provided that the ULS safety factors given in Table 3.7 are increased by a factor of 1.2 and further that the loss of the mooring system will not result in a major pollution or major damage to the unit. Emergency disconnection systems for risers and mooring will be required. Further, the main propulsion of the unit shall be in operation (DNV, 2010).

Table 3.7 Partial safety factors for the ULS according to DNV

Consequence Class	Type of analysis of wave frequency tension	Partial Safety factor on mean tension	Partial safety factor on dynamic tension
1	Dynamic	1.10	1.50
2	Dynamic	1.40	2.10
1	Quasi-static	1.70	
2	Quasi-static	2.50	

(Source: DNV, 2010)

3.4.1 Partial safety factors for the ALS

The design equation for the ALS is identical to the ULS, but the partial safety factors are given in Table 3.8.

Table 3.8 Partial Safety factors for ALS according to DNV

Consequence Class	Type of analysis of wave frequency tension	Partial Safety factor on mean tension	Partial safety factor on dynamic tension
1	Dynamic	1.00	1.10
2	Dynamic	1.00	1.30
1	Quasi-static	1.10	
2	Quasi-static	1.35	

(Source: DNV, 2010)

The combination of an accidental line failure with characteristic loads based on a 100-year return period is, in itself, relatively conservative. Hence, the partial safety factors in table 3.6 are relatively small; i.e. close to unity. These factors should be adequate even when the loading is dominated by the mean tension, provided that 100-year environmental conditions give rise to a significant portion of the mean tension.

3.5 API's Guidelines on Permissible horizontal offset

The guidelines also define the maximum watch circle offset for both intact and damaged conditions in order to maintain riser integrity. The maximum watch circle offset according to API is as follows:

- Maximum Intact Offset < 8% of Water Depth.
- Maximum Damaged (1-line broken) offset < 12% of Water Depth.
- Maximum Offset = Mean + Dynamic

(API RP 2SK, 2005)

The DNV requirements are discussed in section 3.2.2 below.

3.6 DNV's Guidelines on permissible horizontal offset (DNV, 2010)

The horizontal offset from a given reference point shall be within the operational service limitation, including offsets for the intact mooring system after any single failure of a line or in the thruster system.

- When the unit is connected to a rigid or vertical riser (e.g. drilling riser), the maximum horizontal offset is limited by the maximum allowable riser angle at the BOP flex joint. A safety margin of 2.5% of the water depth shall be included.
- Maximum horizontal offset of flexible and steel catenary risers shall not exceed the manufacture specification.
- Maximum environmental conditions for drilling operation are also to take the heave compensating capacity into consideration (DNV, 2010).

When the unit is connected by a gangway to another structure, the positioning system and the gangway structure shall meet the following criteria:

1) The distance between the unit and the installations shall not be less than 10 m at any point.
2) During normal operation an excursion reserve of 1.5 m of the specified maximum excursion of the gangway shall be included.
3) The gangway shall be equipped with alarm in the control room, which shall be activated when the maximum excursion is exceeded.
4) The gangway shall be positioned so that it will not collide with any other structure after a single failure.

3.7 Installation Tolerances

Usually, anchors are installed at the design location where penetration and horizontal and vertical orientations are given within specified tolerance limits. Most installation tolerances need to be addressed in the design process. The industry has commonly used a set of tolerance limits for different anchor types, based on the extent of adverse effects of excessive departures from the design parameters (position, penetration, etc.) relative to the cost of minimizing it (DNV RP E301, 2010). Verticality tolerance for slender piles, however, is sometimes controlled by the geotechnical and structural stability of the pile after self-penetration.

For anchor piles in spread moorings, pile tilt may be more tolerable when it is such that the pile is tilted away from the mooring line; location tolerance is also more liberal if it results in a longer mooring line. In most such instances, pile capacity actually benefits from the tilt or increasing stiffness. Generally, tolerance of the anchor location at the site is controlled by mooring line sensitivity to the anchor location, which is more for taut leg systems than for catenary systems. In Table 3.9, DNV summarizes installation tolerances commonly used by the industry for different types of anchors. Vertically loaded anchors have proven the most tolerant of all anchor types.

Table 3.9 Installation tolerance for anchors according to DNV

	TLP Piles	Catenary and Taut Leg Lines		
		Anchor Piles	Suction Piles	VLAs
Location[3,4]	Radius of 1.0-2.0 ft	-1% to 2% of mooring line length inwards; more outwards		
Penetration	- <1.0 ft[4]; + Few feet [2]			- <1.0 ft[4], + virtually unlimited
Misverticality (Tilt)	±1.0-3.0 deg[1]	±3.0-5.0 deg[1]		N/A
Padeye Misorientation	N/A	±7.5 deg[1]		Virtually ±180 deg

(Source: DNV RP E 301)

We will cite the DNV Guidelines for structural arrangement for mobile mooring below (DNV, 2010).

3.8 Guidelines for Structural Arrangement of Mooring Equipment

1) The anchors shall be effectively secured in transit to prevent movement of anchor and chain due to wave action. The arrangements shall provide an easy lead of the chain cable or wire rope from the windlass or winch to the anchors. Upon release of the brake, the anchor is immediately to start falling by its own weight.
2) If anchors are supported directly by the shell, the shell plating in way of the anchor stowage shall be increased in thickness and the framing reinforced as necessary to ensure an effective supporting of the anchor.
3) Anchors bolsters shall be efficiently supported to the main structure. However, if the anchor bolsters are damaged or torn off, the main structure shall not be significantly damaged.
4) The chain locker shall have adequate capacity and a suitable form to provide a proper stowage of the chain cable, and an easy direct lead for the cable into the chain pipes, when the cable is fully stowed. The chain locker boundaries and access openings shall be watertight. Provisions shall be made to minimize the probability of chain locker being flooded in bad weather. Drainage facilities of the chain locker shall be adopted.

5) Under normal operation of the mooring line provisions shall be made for securing the inboard end. The arrangement shall be such that the mooring line can be easily disconnected in case of emergency. A weak link can be arranged at the inboard end to secure disconnection in case of emergency.
6) Mooring systems with all-wire rope or chain and wire rope anchor lines shall have provisions for securing the inboard ends of the wire rope to the storage drum. This attachment shall be designed in such a way that when including the frictional force being applied through the turns of rope always to remain on the drum it is able to withstand a force of not less than the minimum wire rope breaking strength.
7) The fastening of the wire rope to the storage drum shall be made in such a way that in case of emergency when the anchor and chain or wire rope have to be sacrificed, the wire rope can be readily made to slip from an accessible position. The storage drum shall have adequate capacity to provide a proper stowage of the wire rope.
8) Fairleads fitted between windlass/winch and anchor shall be of the roller type.
9) The windlass or winch, chain stopper and fairlead shall be efficiently supported to the main structure.
10) The nominal equivalent stress in the supporting structures is normally not to exceed 0.8 when subjected to a load equal to the breaking strength of the unit's anchor line. The strength analysis shall be made for the most unfavourable direction of the anchor line, i.e. angle of attack to structure. Detailed information regarding design of supporting structure is given in DNV-RP-C103.
11) Fatigue (FLS) shall be documented for winch/windlass foundation. The design fatigue life for the structural components shall be based on the specified service life of the structure, with service life minimum 20 years (DNV, 2010).

3.9 DNV’s Guidelines on Permissible mooring line length

1) The mooring lines shall have enough length to avoid uplift at anchors for all relevant design conditions in the ULS.
2) Vertical forces on the anchors can be accepted in the ALS, if it is documented that these vertical forces will not significantly reduce the characteristic resistance of the anchors.
3) Anchors designed to withstand vertical forces will be accepted in both ULS and ALS conditions.

4) Unrealistic line lengths to meet the requirements in (1) above shall not be used in the mooring analyses (DNV, 2010).

3.10 DNV's Guidelines regarding Vortex Induced Motions (VIM)

Semi-taut and taut mooring systems with steel wire rope or fiber robe segments can be exposed to VIM which can contribute to the fatigue damage. VIM is caused by vortices shed alternatively from upper and lower side of a cylinder giving rise to oscillatory forces in the transverse direction to the incoming flow as well as in the in-line direction.

- The main effect of VIM on the mooring line forces is an increase in the effective Drag Coefficient (CD).
- For a VIM amplitude on the order of the diameter, the effective CD can be increased by a factor, This increase in CD will have an effect on the wave induced dynamic tension in the mooring line, not on the static (mean) tension. It is assumed that chain is not affected by VIM.
- The possibility of VIM should be checked and the effect on the dynamic tension shall be included in the fatigue evaluation (DNV, 2010).

3.11 API's recommended practice for handling fiber rope mooring lines before and during installation

The following guidelines should be followed when handling fiber rope mooring lines as well as during installation.

- Ropes should not be permanently installed around bollards or fairleads.
- A minimum bending radius should be observed. The minimum bend radius (D/d) with very low line tensions should be larger than 6.
- Torque or twist in the rope should be avoided.
- Fiber ropes should not be run over surfaces which have sharp edges, grooves, nicks or other abrasive features.
- Care should be taken when applying shearing forces to the rope.
- There should be no "hot work" such as welding in the vicinity of the rope.
- Frictional heat from excessive slippage of the fiber rope over a capstan, drum, etc. must be avoided.
- Care should be taken that ropes do not get knotted or tangled.
- Rope contact with sharp gritty materials should be avoided.

• Abrasion or fouling of the mooring line with other anchoring equipment such as anchor, steel wire rope, chain and connectors must be avoided.

• Chasers should not be used on fiber ropes.

•Shark jaw stoppers designed for use with steel wire rope or chain should not be used for handling fiber ropes.

• It should be avoided that the ropes undergo more than 1000 load cycles with a line tension smaller than 5% of the Maximum Breaking Load.

• Pre-deployed lines should not be left buoyed at the surface waiting connection to the platform, unless a minimum line tension of 5% (for polyester) of the Maximum Breaking Load (MBL) is maintained.

• If the fiber rope is laid on the seabed, it must be protected against external abrasion and ingress of abrasive particles (API RP 2SK, 2005).

CHAPTER FOUR

Mooring Line Characteristics

4.1 Chains characteristics

Chain is one of the most popular product used for mooring lines in the offshore industry is. Chain is available in different diameters and grades (as shown in Table 4.1 and 4.2). There are two different designs of chain, studlink and studless chain. The studlink chain is most commonly used for moorings that have to be reset numerous times during their lifetime, e.g. semi-submersibles. Studless chain is often used for permanent moorings (FPSO's, buoys, FPOs).

The studless design has some advantages over studlink chains. The advantages are:

- Studless chain can be delivered in any of the recognized IACS grades R3, R3S and R4 up to and including 160mm
- Studless chain weigh 9% less compared to studlink
- Shackles can be inserted at any position in the studless link design(actual lengths can be shortened at a later stage, no need for end links at certain positions)
- There is no risk of loose studs in studless chain applications
- Studless chain has lower Young's Modulus (typically 80-90% of studlink)

However, studies have shown studless chain in winches has 20% higher tension in the bend area compared to studlink chain. Also, the possibility of kinking of the studless chain is higher than studlink chain (Ohlsson, 1997). A length of studlink chain is stiffer than studless chain. Mechanical properties of chains are shown in Table 4.1 and 4.2 below.

Table 4.1 Mechanical properties of offshore mooring chain

Grade	Minimum yield strength (N/mm^2)	Minimum tensile strength (N/mm^2)	Minimum elongation (%)	Minimum reduction of area (%)
NV R3	410	690	17	50
NV R3S	590	770	15	50
NV R4	580	860	12	50

(Source: DNV, 2010)

Table 4.2 Properties of mooring chains

diameter	Proof load						Break load				Weight	
	R4-RQ4		R3S		R3	RQ3-API	R4-RQ4	R3S	R3	RQ3-API		
	stud	studless	stud	studless	stud-studless	stud-studless	stud and studlless				stud	studless
mm	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kg/m	kg/m
19	331	293	276	267	239	215	420	382	342	324	8	7
20.5	385	340	320	310	278	249	488	443	397	376	9	8
22	442	390	368	356	319	286	560	509	456	431	11	10
24	524	463	436	422	378	339	664	604	541	511	13	12
26	612	541	510	493	442	397	776	706	632	598	15	14
28	707	625	589	570	511	458	897	815	730	691	17	16
30	809	715	674	651	584	524	1026	932	835	790	20	18
32	917	811	764	738	662	594	1163	1057	946	895	22	20
34	1031	911	859	830	744	668	1308	1188	1064	1007	25	23
36	1151	1018	959	927	831	746	1460	1327	1188	1124	28	26
38	1278	1130	1065	1029	923	828	1621	1473	1319	1248	32	29
40	1410	1247	1175	1136	1018	914	1789	1625	1456	1377	35	32
42	1548	1369	1290	1247	1118	1004	1964	1785	1599	1513	39	35
44	1693	1497	1411	1364	1223	1097	2147	1951	1748	1654	42	39
46	1843	1630	1536	1485	1331	1194	2338	2124	1903	1800	46	42
48	1999	1767	1666	1610	1443	1295	2535	2304	2063	1952	50	46
50	2160	1910	1800	1740	1560	1400	2740	2490	2230	2110	55	50
52	2327	2058	1939	1874	1681	1508	2952	2682	2402	2273	59	54
54	2499	2210	2083	2013	1805	1620	3170	2881	2580	2441	64	58
56	2677	2367	2231	2156	1933	1735	3396	3086	2764	2615	69	63
58	2860	2529	2383	2304	2066	1854	3628	3297	2953	2794	74	67
60	3048	2695	2540	2455	2201	1976	3867	3514	3147	2978	79	72
62	3242	2866	2701	2611	2341	2101	4112	3737	3347	3166	84	77
64	3440	3042	2867	2771	2484	2230	4364	3965	3551	3360	90	82
66	3643	3221	3036	2935	2631	2361	4621	4200	3761	3559	95	87
68	3851	3406	3209	3102	2782	2496	4885	4440	3976	3762	101	92
70	4064	3594	3387	3274	2935	2634	5156	4685	4196	3970	107	98
73	4392	3884	3660	3538	3172	2847	5572	5064	4535	4291	117	107
76	4731	4183	3942	3811	3417	3066	6001	5454	4884	4621	126	116
78	4962	4388	4135	3997	3584	3216	6295	5720	5123	4847	133	122
81	5317	4702	4431	4283	3840	3446	6745	6130	5490	5194	144	131
84	5682	5024	4735	4577	4104	3683	7208	6550	5866	5550	155	141
87	6056	5355	5046	4878	4374	3925	7682	6981	6252	5916	166	151
90	6439	5693	5365	5187	4650	4173	8167	7422	6647	6289	177	162
92	6699	5923	5582	5396	4838	4342	8497	7722	6916	6544	185	169
95	7096	6275	5913	5716	5125	4599	9001	8180	7326	6932	198	181
97	7365	6513	6138	5933	5319	4774	9343	8490	7604	7195	206	188
100	7776	6876	6480	6264	5616	5040	9864	8964	8028	7596	219	200
102	8054	7122	6712	6488	5817	5220	10217	9285	8315	7868	228	208

(Source: Vryhof Anchor manual, 2010)

4.2 Wire Rope Characteristics

Compared to chains, wire ropes have a lesser weight than chains, for the same breaking load and also, a higher elasticity. Common wire ropes used in offshore mooring lines are 6-strand and spiral strand. The wire rope is terminated with a socket (for instance open spelter, closed spelter) which facilitates connection to the other components in the mooring system. Generally, wire ropes are susceptible to damage by corrosion than chains.

4.2.1 Wire rope properties

A wire rope consists of several strands, usually 6, laid helically in one or more layer(s). A spiral strand rope is just one single strand. The behavior characteristics of wire rope and its durability under a given set of operating conditions are largely determined by certain basic features of the design. These features include:

- The number of strands in the rope
- The number and arrangement of wires in the strands
- The tensile strength of the wires
- The type of core in the wire
- Special processing applied such as pre-forming and post-forming
- Zinc coating and lubrication

Wire ropes are made in ordinary lay or in Lang's lay. In ordinary lay, the strands and rope are laid in opposite direction, while in Lang's lay, both strand and ropes are laid in the same direction. The ordinary lay ropes have good resistance to kinking and are therefore easy to handle. They have better resistance to crushing and distortion of the outer wires than Lang's lay ropes. This is due to the short length of exposed wires on the crowns of strands, which are in contact with small sheaves and drums with multiple layers.

Conversely, Lang's lay ropes will, due to longer length of wire exposed to the crowns offer better resistance to abrasion and bending fatigue. The use of Lang's lay will often necessitate a construction with larger outer wires and thereby ensuring increased resistance to abrasion without sacrificing bending life. Due to the tendency of Lang's lay to un-lay under load, it is only recommended for use when both ends are secured (ScanRope, 1999).

Lang's lay rope is more easily crushed and flattened on drum and should not be used when irregular drum winding conditions are present. They are also more susceptible to damage resulting from handling abuse, bending over extremely small sheaves and pinching in undersized sheave grooves. Lang's lay rope with steel core is usually recommended where there is more than one layer of rope on the drum and winding is tight and regular.

4.2.2 6-Strand Wire ropes

Steel wire ropes consisting of six strands are the most common type and are suitable for various engineering purposes. The design is the most ideal considering construction stability and equal sharing of the applied tension between strands and steel core. 6-strand wire ropes provide optimum crushing resistance at low safety factors and with multiple layers on the drum (Scan Ropes, 1999). 6-strand wire ropes are standard ropes, and should always be considered first when selecting wire ropes. Special characteristics of 6-strand ropes are:

- High resistance to deformation
- No crushing or jamming on winch
- High abrasion resistance
- Excellent fatigue properties giving longer lifetime
- High strength gives better safety
- Low elongation
- Maintenance free

The mechanical properties of 6-strand wire ropes are shown in Table 4.3 below.

Table 4.3 Mechanical Properties of 6-Strand wire rope

Properties of six strand wire rope						
Diameter mm	(inch)	MBL kN	Axial Stiffness MN	Rope weight kg/m	Submerged rope weight kg/m	Torque Factor Nm/kN
64	2.5	3360	189.4	17.3	15.3	4.7
71	2.75	3990	233.0	20.8	18.3	5.2
77	3	4767	278.8	25.7	22.7	5.8
83	3.25	5399	319.7	29.5	26.0	6.3
89	3.50	6414	415.2	35.0	30.9	6.9
96	3.75	6965	483.8	40.5	35.7	7.5
102	4	7799	573.5	44.5	39.3	8.1
108	4.25	8240	642.1	49.8	43.9	8.6
114	4.50	9172	707.0	55.3	48.8	9.1
121	4.75	10055	775.7	60.6	53.5	9.7
127	5	11134	866.6	67.7	59.8	10.2
133	5.25	11728	912.9	73.8	65.5	10.6
140	5.50	12925	1006.1	80.9	71.7	11.2

Note: MBL based on 10 years design life.
Torque factor presented in the last column is an approximate value at 20% applied load.

(Source: Vryhof Anchor manual, 2010)

4.2.3 Spiral Strand wire rope

Spiral strands are used in various static load-carrying applications where high strength and high modulus of elasticity is required. The wires are finally galvanized to protect them from corrosion for a long time. The tensile strength of the wires is normally 1370N/mm^2, but higher strength can be delivered on request (Scan Ropes, 1999).

Spiral strands may be pre-stretched to remove the constructional looseness inherent in the strand during the closing of the wires. The operation of pre-stretching makes the spiral strand more stable and nearly elastic, and it permits also smaller tolerance on length measurements under prescribed tensions. Common application of spiral strands wire ropes are suspender cables on suspension bridges and other tension members in straight-line pull with end sockets. The Mechanical Properties of Spiral strand wire ropes are shown in Table 4.4 below.

Table 4.4 Mechanical Properties of Spiral strand wire ropes

Properties of spiral stand wire rope							
Nominal Diameter mm (inch)	MBL kN	Axial Stiffness MN	Nominal Weight in kg/m		Submerged nominal weight kg/m	Nominal Steel Area mm²	Sheathing Thickness mm
			Unsheathed	Sheathed			
76 (3)	5647	557	28.4	30.4	23.8	3377	8
82 (3.25)	6550	627	33.0	35.1	27.5	3917	8
90 (3.5)	7938	760	39.9	42.9	33.4	4747	10
95.5 (3.75)	8930	855	44.9	48.1	37.5	5341	10
102 (4)	10266	982	51.6	55.3	43.1	6139	11
108 (4.25)	11427	1093	57.5	61.3	48.0	6834	11
114 (4.5)	12775	1222	64.2	68.3	53.6	7640	11
121.5 (4.75)	14362	1353	72.2	76.5	59.7	8589	11
127 (5)	15722	1481	79.1	83.6	66.0	9403	11
133 (5.25)	17171	1599	86.8	91.5	72.4	10314	11
141 (5.5)	19180	1799	97.5	102.4	81.5	11609	11
146.5 (5.75)	20469	1940	105.1	110.2	87.7	12515	11
153 (6)	22070	2110	114.5	119.7	95.5	13616	11

(Source: Vryhof Anchor manual)

4.3 Synthetic fiber ropes characteristics

High Modulus Synthetic Fiber Rope — a rope made from High-modulus fibers such as Aramid and High-modulus polyethylene (HIVPE). Compare to usual synthetic fiber ropes made of nylon, polyester and polypropylene these fiber ropes are much stronger.

Types of material used in the construction of synthetic fiber ropes according to (RIFLEX User manual, 2010) are:

ARAMID fiber has high strength, low stretch and reasonable ultraviolet (UV) resistance and resist sufficiently against cutting and abrasion. Abrasion resistance can be increased by sheathing. The ropes do not float or melt but char at high temperatures.

HMSF ropes have high strength, low stretch and good UV resistance. They do have very good fatigue resistance against cutting, tension, abrasion and bending but limited temperature resistance.

NYLON has special resistance against sustained loading. It is highly resist to chemical attack from alkalis, oils and organic solvents, but will be damaged by acids. It has a high elasticity and when it is wet the strength will be reduced to 80% of dry strength. When comparing this rope with other ropes or ordering nylon lines dry and wet MBL should be considered.

POLYESTER: among the man-made fiber ropes, it is the heaviest fiber with a lowest extension under load except HIVSF and excellent abrasion resistance but is not as strong as nylon. It does not float and highly resist against acids, oils and organic solvents but it damage by alkalis.

POLYPROPYLENE: it is not as strong as polyester or nylon but has approximately the same elasticity as polyester. It has a low melting point and tends to fuse under high friction. Cyclic load characteristics of Polypropylene are low and it has poor ultraviolet resistance. It can be float so it is not recommended to use for mooring lines.

POLYESTER/POLYPROPYLENE: there are several mixes of these two materials which will be used for mooring line. It is lighter than polyester but heavier than polypropylene and its strength is about 50% between the two. It is resist against acids, alkalis and oil. It does not float.

Unlike steel, synthetic fiber ropes exhibit axial stiffness characteristics which are non-linear and vary with time and loading history. Advantages of using synthetic fiber ropes for mooring lines include a reduction in mooring line weight and hence increased vessel payload, reduction in vessel offset and associated riser costs, reduction in vertical loads and associated structural costs, reduction in the extreme line dynamic tension due to lower tensile stiffness, reduction in installation cost.

Disadvantages of using synthetic fiber moorings are limited design data for large size ropes and lack of long term service experience. Fiber ropes may be used as segments in steel catenary systems, or in taut leg mooring systems. The subtle differences from that of steel wire/chain mooring systems include the non linear stiffness, the minimum tension requirements, the requirement for location of the fiber rope segment to be away from both fairlead and seafloor , creep phenomenon, and different handling procedures (Werdal, 2002). The mechanical properties of polyester ropes are shown in Table 4.5 below.

Table 4.5 Mechanical properties of Polyester ropes

Polyester mooring line: strength table								
Diameter mm	MBL k/N	Total weight kg/m		Submerged weight kg/m		Stiffness kN		
		@2% MBL	@20% MBL	@2% MBL	@20% MBL	EA[1]	EA[2]	EA[3]
113	3723	8.8	8.2	2.1	1.9	7.19e+04	8.43e+04	1.10e+04
137	5754	12.9	12.0	3.1	2.9	1.18e+05	1.38e+05	1.80e+05
154	7446	16.2	15.1	3.9	3.6	1.57e+05	1.84e+05	2.40e+05
169	9138	19.5	18.2	4.7	4.4	1.96e+05	2.30e+05	2.99e+05
183	10830	22.8	21.2	5.5	5.1	2.35e+05	2.76e+05	3.59e+05
195	12522	26.0	24.2	6.2	5.8	2.74e+05	2.22e+05	4.19e+05
207	14215	29.2	27.2	7.0	6.5	3.14e+05	3.68e+05	4.79e+05
227	17261	35.0	32.6	8.4	7.8	3.53e+05	4.14e+05	5.39e+05
245	20307	40.7	37.9	9.7	9.1	3.27e+05	3.83e+05	4.99e+05

Note : Minimum Breaking Load (MBL) in spliced condition.
Weights are presented for a rope loaded to 2% and 20% of MBL
[1] cycling between 10 - 30 % MBL
[2] cycling between 20 - 30 % MBL
[3] cycling between 40 - 50 % MBL

(Source: Vryhof Anchor manual)

The fibers currently being evaluated for use in permanent or temporary deepwater moorings are polyester (polyethylene terephthalate), HMPE (High Modulus Polyethylene) and nylon (polyamide).
For taut leg mooring systems, the synthetic fiber rope axial stretch provides load extension characteristics, which the catenary geometry traditionally supplied in the conventional steel system.

The lower modulus of elasticity of polyester compared with steel and relatively low costs make it suitable for many deep water taut leg mooring systems. Other fibers such as HMPE may be more suitable for applications where a smaller rope diameter is required (e.g. for frequent handling) or for ultra –deep water taut leg mooring applications. Currently polyester is considered to be a good candidate for the offshore mooring application due to its low stiffness which introduces less tension during design storm, good resistance to axial compression fatigue, good fatigue properties, good strength to weight ratio, and good creep resistance (ScanRope, 1999). A comparison of properties of polyester ropes and Dyneema ropes is shown in table 4.6 below.

Table 4.6 Comparison of properties of Polyester ropes and Dyneema ropes

Rope properties		
	Polyester	Dyneema
Material	Polyester	High Modulus PolyEthylene
Construction	Parallel strand construction	Parallel strand construction
Protective cover	Polyester	Composite yarn
Color of rope	White with marker yarns	White
Specific gravity	1.38 - sinks	0.975 - floating
Melting point	251° C	145° C
Abrasion resistance	Excellent	Excellent
UV resistance	Excellent	Good
Temperature resistance	Workable at sub-zero temperatures	Medium
Chemical resistance	Good	Excellent
Water absorption/fibers	< 0.5%	< 0.05%
Water uptake	+ / - 30%	n.a
Dry & weight conditions	Wet strength equals to dry strength	Wet strength equals to dry strength

(Source: Vryhof Anchor manual, 2010)

4.3.1 Rope Construction

There are many types of fiber rope construction. The polyester deep water mooring rope is often manufactured as a single laid structure using ¨wire rope'' techniques. The rope is composed of nine outer strands, laid, in a right hand direction, over a 3-strand, left hand laid core. This combination results in a rope with very low torque value. The rope is subsequently given a braided polyester jacket to provide abrasion protection, primarily during deployment. A minimum bend diameter of ten times the rope diameter is generally recommended although the rope will accept a factor of four times the rope diameter under low load situations.

4.3.2 Terminations

Deep water mooring lines may be terminated by means of eye splices. The protected eyes are arranged around grooved spool pieces fitting onto the pins of connecting shackles. The spool pieces can be made from steel or a lightweight composite material**.**

4.3.3 Rope elongation and stiffness

Fiber ropes are constructed from fiber materials with visco-elastic properties. The rope stiffness increases with mean load, and decreases with cyclic load and with load relaxation over time. After the rope has been tensioned to allow bending and cyclic load, and relaxation has occurred for some time, the stiffness of fiber ropes tends toward a linear function of mean load and load range. Continued elongation under load may result to need to re-tension the lines.

4.3.4 Durability and Fatigue

Durability and fatigue are important factors which have significant effect on the life of synthetic fiber ropes for deep water mooring. Other factors which are subject of research include hydrolysis, heating and internal abrasion, tension fatigue and axial compressive fatigue.

4.3.5 External abrasion and cut resistance

Jacketing is usually carried out on fiber ropes where external abrasion poses a threat while in service, during installation or during recovery (if applicable for movable temporary moorings). An important concept is to keep the fiber rope away from the sea bed. This is why there is normally a piece of chain between the fiber rope and the anchor. If the fiber rope comes near the sea bed, sand particles will come in between the fibers and the rope. When the rope is not stretched and slacked over time, the particles will cut the fibers and damage the rope eventually.

4.3.6 Torque and Twist effect

Torque compatibility among different mooring components consisting of synthetic fiber rope, chain or wire should be considered. Excessive twisting from unbalanced torque should be avoided during handling, installation, operation and recovery. For example, a short section of 6-strand wire rope in series with a long parallel construction fiber rope of low rotational stiffness may allow excessive twist to occur in the wire rope, hence significantly shortening the design life of the wire rope. It is far preferable to attach wire and fiber ropes when both have laid constructions.

4.3.7 Marine growth

Synthetic fibers suitable for moorings are unlikely to show any chemical degradation as a result of exposure to marine growth. Marine organisms with hard shells may possibly grow between the rope jacket and the load-bearing core and cause abrasion damage to core yarns. Soft marine growth may limit visibility and hence affect the ability of an ROV to inspect the rope. Marine growth may also influence the drag loading on the line and hence the loading on the whole mooring system. For operations where marine growth is a concern, the fiber ropes should be placed below the marine growth zone. If marine growth is to be removed mechanically, this should be done in such a way that avoids damage to the rope itself.

4.3.8 Fish bite

In the unlikely event of fish bite, or it is necessary to come up with means of minimizing such damages by carefully considering the selection and design of the fiber rope for different applications. The frequency of Subsea inspection by ROV's should be increased.

4.3.9 Hydrolysis

Hydrolysis is the chemical breakdown of a compound due to reaction with water. Strength losses due to hydrolysis in polyester ropes will not occur to an appreciable extent unless the temperature is greater than 30^0 C for long period of time. HMPE is not subjected to hydrolysis.

4.3.10 Effects of Water depth

At 2000 meters water depth, the hydrostatic pressure is 20MPA, which represents about 2 % of the strength of polyester yarns. This would have a negligible effect on yarn mechanical properties, and would only be responsible for a small transverse strain and the accompanying axial strain on a rope.

CHAPTER FIVE

DYNAMIC ANALYSIS

5.0 Overview

It is important to design mooring systems properly to ensure that the horizontal motions of the offshore vessels are minimal during marine operations, so as not to cause damage to the production risers or the sub-sea equipment. In this chapter, the dynamic analysis of mooring systems is concerned with analyzing a body (or a collection of bodies) which are connected to the sea floor by a system of mooring lines (catenary or taut). The general purpose of the mooring lines is to secure the vessel and prevent the vessel from drifting away during marine operations. There are two aspects of this analysis, the forces which the lines exert on the body and the forces which the environment exerts on the body. In this thesis, the bodies discussed are offshore vessels.

(Couliard, 1999) states that "the most common type of mooring employed in shallow waters is the catenary system (wire rope or chain), or a combination of both; which provides restoring forces through the weight of the line and its change in configuration arising from vessel motion".

The weight of the mooring line normally increases with increasing water depth, and eventually this places an unacceptable limitation on the working payload of the vessel. The current practice in deep water is to use catenary/taut leg synthetic fiber rope moorings, in addition to chains. The heavy weight of a chain mooring line in deep water is a major contributor to the mooring line tension. The weight of the chain also induces a vertical force on the moored vessel. To address this problem, hybrid mooring lines, such as lighter synthetic fiber ropes with chains, have been proposed.

Fiber ropes are lightweight and more extensible than steel, and when used in a taut-leg configuration they provide restoring forces through axial stretching rather than geometry changes (Couliard, 1999). This chapter is concerned with the dynamic analysis of such systems.

5.1 Guidiing Principle of mooring systems

Environmental forces on the drilling vessel are counterbalanced by the restoring forces which are supplied by tensions in the mooring lines. In turn, the mooring line tensions are transmitted to anchors on the sea floor.

5.2 Dynamic Analysis

The mooring system is analyzed using OrcaFlex software (dynamic analysis software from Orcina Ltd, www.orcina.com). The mathematical model of the real-world system is built using the various modeling facilities provided by OrcaFlex. The model consists of the marine environment to which the system is subjected, the offshore vessel, mooring lines, anchors and connectors placed in the environment and connected together as required. The objects in the model represent the structures being analyzed and the environment determines the current, wave excitation, etc. to which the objects are subjected.

In order to study the static and dynamic behaviour of catenary and taut line moorings in deep waters, it is important to take into consideration the material non-linearity and the full range of excitation forces arising from vessel motions and environmental forces (API RP 2SK, 2005).

The OrcaFlex software provides facility for calculating the mooring loads and mooring component specifications needed to keep the vessel within the specified operation area, in intact and damaged states. Outputs from the mooring calculations are then used to calculate the Response Amplitude Operators (RAO) of the vessel. These frequency response spectrums will be compared to the frequencies of the environment to see if any dangerous resonance responses of the vessel were possible. Also, the tensions in the mooring lines are evaluated (OrcaFlex manual, 2012). Generally, we have two forms of mooring; spread mooring and single point mooring.

5.3 Spread Mooring

In this thesis, spread mooring is considered in the dynamic analysis. In a typical spread mooring system, groups of mooring lines are terminated at the corners of the vessel, holding a stable vessel heading. Spread mooring has the following advantage over single point mooring: spread mooring system can be designed to hold the vessel on location regardless of the direction of the environment (API RP 2SK, 2005). The mooring line can be chain, wire rope, synthetic fiber rope, or a combination of the three. Either drag embedment anchors or piles can be used to terminate the mooring lines on the sea floor.

5.4 Mooring Geometry

The two most common mooring geometries are catenary and taut. A Catenary mooring system approaches the sea floor horizontally at zero degrees. This means that the mooring line lies horizontally on the sea floor at some appreciable distance to the anchor. Catenary mooring lines reduce the vertical loads on the anchor. Catenary systems are generally spread over a large area on the seabed.

Alternatively, in taut leg mooring, the mooring lines approach the sea floor at an angle. Taut systems reduce vessel motions but also increase line tensions. Furthermore, taut mooring geometry decreases the seafloor spread (the area used for mooring purposes on the sea floor), and the length of the mooring line. In this thesis, we shall consider both catenary and taut leg mooring systems.

5.5 OrcaFlex Model

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The model comprises an offshore vessel, mooring lines (combination of fiber ropes and chains), links and winches. Both Catenary Anchor length Mooring (CALM) and Taut Leg Mooring are analyzed in this thesis. The vessel is mathematically modeled as a rigid body with a discrete point of attachment for each mooring line. Each mooring line is treated as a single-component cable terminating at drag embedment anchor. The limiting tensions for each cable in complete and partial catenary configurations are determined from the cable strength and anchor holding capacity (OrcaFlex manual. 2012). A brief description of each component of the OrcaFlex model is given below.

5.5.1 Vessels

Vessels are used to model ships, floating platforms, barges etc. They are rigid bodies whose motions are prescribed by the user. The motion can be specified in a number of ways: directly by a time history motion data file or specifying Response Amplitude Operators (RAOs) for each of 6 degrees of freedom (surge, sway, heave, roll, pitch and yaw), or indirectly by giving first order wave load RAOs (OrcaFlex manual, 2012). Vessels can also be driven around the sea surface, at user specified velocities and headings, during the course of the simulation.

5.5.2 6D- Buoys

6D buoys are much more sophisticated than 3D buoys. They are rigid bodies with the full 6 degrees of freedom. That is, OrcaFlex calculates both their translational and rotational motion. Several different types of 6D Buoy are available, for modeling different sorts of marine object.

5.5.3 Lines

The OrcaFlex software define lines as catenary elements used to represent pipes, flexible hoses, cables, mooring lines, etc. Line properties may vary along the length, for example to allow a buoyant section to be represented. Line ends may be fixed or free, or attached to other objects such as Vessels or Buoys, and ends can be disconnected in the course of a simulation. Each line can also have a number of attachments. These are elements attached to lines at user-specified locations, and provide a convenient way of modeling items such as floats, clump weights, or drag chains (OrcaFlex manual, 2012).

5.5.4 Links

Links are mass-less connections linking two other objects in the model. Two types are available: Tethers and Spring/Damper units. Tethers are simple elastic ties while spring / dampers are combined (linear or non-linear) spring + damper units (OrcaFlex manual, 20102).

5.5.5 Winches

Winches are also mass-less connections linking two (or more) objects in the model. The connection is by a winch wire, which is fed from and controlled by a winch drive mounted on the first object. The winch drive can be operated in either constant speed mode, in which it pays out or hauls in the winch wire at a user-specified rate, or else in constant tension mode, in which it applies a user-specified tension to the winch wire (OrcaFlex Manual, 20102).

The OrcaFlex Software performs the following analysis on the model:

- Modal Analysis, in which OrcaFlex calculates and reports the undamped natural modes of the model, or of an individual line in the model.
- Static analysis, in which OrcaFlex calculates the static equilibrium position of the model; current and wind loads are included, but not wave loads.
- Dynamic analysis, in which OrcaFlex carries out a time simulation of the response of the system to waves, current and a range of user-defined inputs. A choice of implicit and explicit integration scheme is offered.

5.6 Mooring Pattern

Three mooring solutions are analyzed in this thesis.

CASE 1

An eight symmetric line mooring system where the lines are spaced 45° apart. The mooring lines comprise chain and Polyester fiber rope. The mooring geometry is Catenary mooring system.

Total length of mooring line = 900m

Water depth = 500m

Wave theory: Dean Stream

Type of waves: Regular waves

Duration: 115 seconds

Mooring line structure: Chain - Fiber rope- Chain

CASE 2

An eight symmetric line mooring system where the lines are spaced 45° apart. The mooring lines comprise Wire rope and Chain. The mooring geometry is catenary mooring system.

Total length of mooring line = 850m

Water depth = 500m

Wave theory: Dean Stream

Type of waves: Regular waves

Duration: 115 seconds

CASE 3

An eight symmetric line mooring system where the lines are spaced 45° apart. The mooring lines comprise chain and Wire rope. The mooring geometry is Catenary mooring system.

Total length of mooring line = 800m

Water depth =500

Wave theory: Dean Stream

Type of waves: Regular waves

Duration: 115 seconds

These solutions are selected to reflect modern mooring designs. The objective of the analysis is to

- Carry out static analysis in which OrcaFlex calculates the static equilibrium position of the model when current and wind loads are included
- Calculate forces and tensions in the mooring lines based on the prevailing environmental conditions.
- Use OrcaFlex software to perform dynamic analysis of different ***mooring lines*** to determine the design criteria for a range of mooring/anchoring systems for different offshore vessels
- Compare the results for the different mooring solutions.

5.7 Environmental Criteria

The design environments for mobile moorings are lower than those for permanent moorings. The lower design environmental criteria for mobile moorings are based on the consideration that the consequence of a mooring failure would generally be less severe. This can be illustrated by comparing a MODU with an FPS. In many instances, a MODU can at least disconnect and may even lay down its drilling riser. In the case of tropical storms, it may be possible to move the vessel before the arrival of a storm. By contrast, an FPS is unlikely to be movable from location, and may not even have quickly retrievable risers (API RP 2SK, 2005).

The industry recognizes two classifications of environmental condition when evaluating mooring system strength: maximum design condition and maximum operating condition.

According to API RP 2SK, the maximum design condition is defined as that combination of wind, waves, and current for which the mooring system is designed. Mooring systems should be designed for the combination of wind, wave, and current conditions causing the extreme load in the design environment. In practice, this is often approximated by the use of multiple sets of design criteria. For example, in the case of a 100-year design environment, three sets of criteria are often investigated:

a) The 100-year waves with associated winds and currents,
b) The 100-year wind with associated waves and currents, and
c) The 100-year current with associated wave and wind.

The most severe directional combination of wind, wave, and current should be specified for the permanent installation being considered, consistent with the site's environmental conditions. Special attention should be given to certain floating structures such as large ship-shaped vessels, which are dominated by low frequency motions. Since low frequency motions increase with decreasing wave periods, the 100-year waves may not yield most severe mooring loads. Lower waves with shorter periods could yield larger low frequency motions and thus higher mooring loads (API RP 2SK, 2005).

5.8 Method of Analysis

A quasi-static analysis method is often used for evaluating the performance of a mobile mooring system, and the effects of line dynamics are accommodated through the use of a relatively conservative safety factor. A more rigorous dynamic analysis is required for the final design of a permanent mooring system, and the factor of safety is relaxed to reflect that some uncertainty in line tension prediction is removed. Dynamic analysis can also be performed for mobile moorings. A fatigue analysis is not required for mobile mooring systems. Because of abuse from frequent deployment and retrieval, many mooring components of a mobile mooring system are replaced before they reach their fatigue limits. However, for permanent installation, fatigue is an important design factor, and a fatigue analysis should be performed. In this chapter we will focus on dynamic analysis (API RP 2SK, 2005).

5.8.1 Dynamic Analysis method

Dynamic analysis accounts for the time varying effects due to mass, damping, and fluid acceleration. In this approach, the time-varying fairlead motions are calculated from the vessel's surge, sway, heave, pitch, roll, and yaw motions. Dynamic models are used to predict mooring line responses to the fair-lead motions (API RP 2SK, 2005).

Two methods, a frequency domain and a time domain analyses, can be used for predicting dynamic mooring loads. In the time domain method, all nonlinear effects including line stretch, line geometry, fluid loading, and sea bottom effects can be modeled. The frequency domain method, on the other hand, is always linear as the linear principle of superposition is used. Methods to approximate non-linear effects in the frequency domain and their limitations should be investigated to ensure acceptable solutions for the intended operation.

(API RP 2SK, 2005) describes four primary nonlinear effects that can have an important influence on mooring line behavior:

a) Nonlinear Stretching Behavior of the Line: The strain or tangential stretch of the line is a function of the tension magnitude. Nonlinear behavior of this type typically occurs only in synthetic materials such as polyester. Chain and wire rope can be regarded as linear. In many cases the nonlinearity can be ignored and a linearized behavior assumed, using a representative tangent or secant modulus.

b) Changes in Geometry: The geometric nonlinearity is associated with large changes in shape of the mooring line.

c) Fluid Loading: The Morrison equation is most frequently used to represent fluid loading effects on mooring lines. The drag force on the line is proportional to the square of the relative velocity (between the fluid and the line), hence is nonlinear.

d) Bottom Effects: In many mooring designs; a considerable portion of the line is in contact with the seafloor. The interaction between the line and the seafloor is usually considered to be a frictional process and is hence nonlinear.

5.8.2 Mooring Systems Conditions

Mooring analysis can be carried out for intact, damaged and transient conditions. Definitions of those conditions are given below:

1) *Intact Condition*: This is a condition whereby all mooring lines are intact, i.e. no line is broken.
2) *Damaged Condition*: This is a condition whereby the vessel oscillates around a new mean position after one or more of the mooring line is broken or when the thruster system fails.
3) *Transient Condition*: This is a condition whereby the vessel is subjected to transient motions after a mooring line is broken or a thruster system fails. Safety factors for the different conditions according to API and DNV are given in Chapter three.

5.8.3 Analysis procedure for Spread Mooring Systems

In a mooring strength analysis based on the approach of frequency domain vessel dynamics, the mean position of the vessel is first determined by the force equilibrium in the surge, sway, and yaw directions. For vessels equipped with a spread mooring system where the yaw moment will not have a significant impact on the vessel heading and line tension, the yaw moment can be neglected. The responses to wave and low frequency excitations are then calculated and added to the mean position. The procedure outlined below is recommended by API RP 2SK, 2005 and adopted in this thesis.

1) Determination of environmental criteria such as wind and current velocities, significant wave heights and periods, their relative directions, storm duration, and wind and wave spectrum for both the maximum design, and operating conditions.
2) Determination of the mooring pattern, the characteristics of chain, wire, and synthetic rope to be deployed, and the initial tension.
3) Determination of the mean environmental loads acting on the hull by using the model test data.
4) Determination of the vessel's mean offset due to the mean environmental loads using static mooring analysis approach which should account for line stretching and friction.
5) Determination of the low frequency motions. Since calculation of low frequency motions requires the knowledge of mooring stiffness, the mooring stiffness at the mean offset should be determined first using a static mooring analysis approach.
6) Determination of the significant and maximum wave frequency vessel motions from a hydrodynamic motion analysis or model test data.
7) Determination of the vessel's maximum offset, suspended line length, maximum tension, and anchor load. For quasi-static analysis, the wave frequency line tensions are calculated by static catenary equations. For dynamic analysis, the wave frequency line tensions are calculated by frequency domain or time domain line dynamics.
8) Comparison of the maximum vessel offset, suspended line length, maximum line tension and anchor load from step 7 with the design criteria. If the criteria are not met, modify the mooring design and repeat the analysis.

5.9 Mooring line theory

The aim of this section is to determine a function, Y=f(X) that describes the curve of the mooring line (catenary equation). We will make the following assumption in this derivation.

- Negligible stiffness.
- Uniformly distributed load.

For the purpose of this thesis, the catenary will be analyzed for X>=0. The following figure shows the catenary from an arbitrary point P(x, y) to the touch down point, (0, 0), taken as the origin.

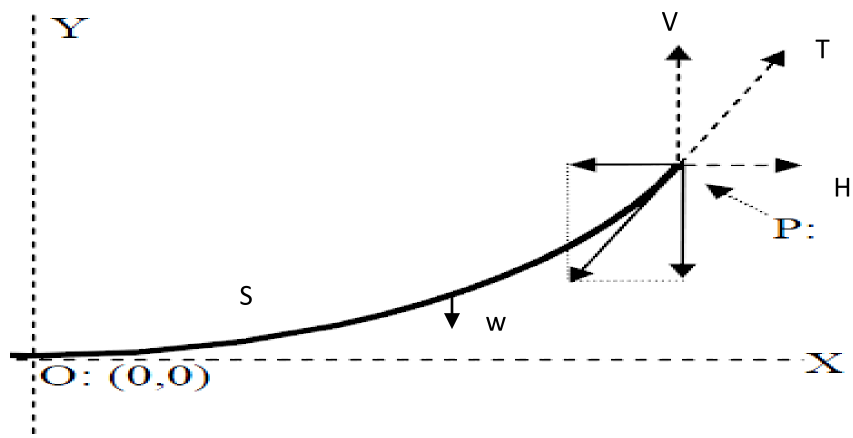


Fig 5.1 Catenary Schematic from inflection point to touch down point

Notations definition

T= Applied tension at the top of the catenary.

H= Horizontal component of the tension.

S= Catenary suspended length.

w= Weight per unit length.

V= Vertical component of tension.

P(x, y) = Arbitrary point on the mooring line.

From Fig 5.1, we can see that: at any point on the catenary, a tangent to the curve equals the tangent to the forces which makes up the tension in the mooring line. Hence, a relationship can be established between the forces and the slope of the curve as follow:

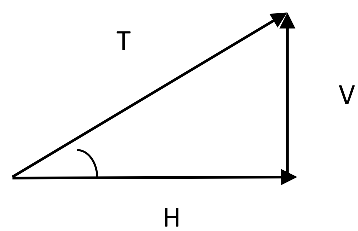
$$\frac{dy}{dx} = \frac{V}{H} = Y' \qquad (1)$$

Also, the tensile force in the Y direction (V) at any point P(x, y) in the mooring line must be responsible for lifting the entire line segment extending from (0, 0) to P(x, y). Therefore,

$$V = ws \qquad (2)$$

Also,

$$\frac{\mathrm{ds}}{\mathrm{dx}} = \frac{\mathrm{T}}{\mathrm{H}} \qquad (3)$$



From the above triangle, using Pythagoras theorem,

$$T^2 = V^2 + H^2$$

$$\mathrm{T} = \sqrt{\mathrm{V}^2 + \mathrm{H}^2}$$

Therefore,

$$\frac{\mathrm{ds}}{\mathrm{dx}} = \frac{\sqrt{\mathrm{H}^2 + \mathrm{V}^2}}{\mathrm{H}}$$

Since V= ws,

$$\frac{\mathrm{ds}}{\mathrm{dx}} = \frac{\sqrt{\mathrm{H}^2 + \mathrm{ws}^2}}{\mathrm{H}} = \sqrt{1 + \left(\frac{\mathrm{ws}}{\mathrm{H}}\right)^2} \qquad (4)$$

Therefore,

$$\frac{\mathrm{ds}}{\sqrt{1+\left(\frac{ws}{H}\right)^2}} = dx$$

Integrating both sides,

$$\int_0^s \frac{ds}{\sqrt{1+\left(\frac{ws}{H}\right)^2}} = \int_0^x dx$$

The above integral expression can be written in standard form as follows

$$\int_0^s \frac{ds}{\sqrt{\left(\frac{w}{H}\right)^2 s^2+\left(\frac{w}{H}\right)^2\left(\frac{H}{w}\right)^2}} = \int_0^x dx$$

$$\int_0^{\mathrm{s}} \frac{\mathrm{ds}}{\frac{\mathrm{w}}{\mathrm{H}}\sqrt{\mathrm{s}^2+\left(\frac{\mathrm{H}}{\mathrm{w}}\right)^2}} = \int_0^{\mathrm{x}} \mathrm{dx}$$

Therefore,

$$\frac{H}{w}\int_0^s \frac{ds}{\sqrt{s^2+\left(\frac{H}{w}\right)^2}} = \int_0^x dx$$

But from mathematical integration table,

$$\int \frac{\mathrm{dx}}{\sqrt{\mathrm{x}^2+\mathrm{a}^2}} = \mathrm{Sinh}^{-1}\left(\frac{\mathrm{x}}{\mathrm{a}}\right) + \mathrm{c}$$

Therefore,

$\frac{\mathrm{H}}{\mathrm{w}}\mathrm{Sinh}^{-1}\left(\frac{\mathrm{s}}{\mathrm{H}/\mathrm{w}}\right) = \mathrm{x}$, which implies that;

$$Sinh^{-1}\left(\frac{ws}{H}\right) = \frac{wx}{H}$$

Therefore,

$$\frac{ws}{H} = Sinh\left(\frac{wx}{H}\right) \qquad (5)$$

Substituting for $\frac{\text{ws}}{\text{H}}$ in equation (4) gives

$$\frac{ds}{dx} = \sqrt{1 + Sinh^2\left(\frac{wx}{H}\right)} = \sqrt{Cosh^2\left(\frac{wx}{H}\right)} = Cosh\left(\frac{wx}{H}\right)$$

Thus,

$$\frac{\text{ds}}{\text{dx}} = \text{Cosh}\left(\frac{\text{wx}}{\text{H}}\right) \qquad (6)$$

$$\frac{\text{dy}}{\text{dx}} = \frac{\text{V}}{\text{H}} = \frac{\text{ws}}{\text{H}} = \text{Sinh}\left(\frac{\text{wx}}{\text{H}}\right)$$

$$\frac{\text{dy}}{\text{dx}} = \text{Sinh}\left(\frac{\text{wx}}{\text{H}}\right)$$

$$\text{dy} = \text{sinh}\left(\frac{\text{wx}}{\text{H}}\right)\text{dx}$$

Integrating both sides,

$$\int_0^y dy = \int_0^x \sinh\left(\frac{wx}{H}\right) dx$$

But $\int \sinh \text{ax} = \frac{1}{\text{a}}\text{Cosh ax} + \text{c}$

Therefore,

$$y = \frac{H}{w} \text{Cosh} \left(\frac{wx}{H} \right) + c \qquad (7)$$

The value of the constant C can be obtained by substituting the boundary condition (x, y) = (0, 0) into equation (7) as follows

$$0 = \frac{H}{w} Cosh(0) + C$$

This implies that $C = -\frac{H}{w}$

Substituting back the value of C into equation (7) yields:

$$y = \frac{H}{w} Cosh\, \frac{w}{H} x - \frac{H}{w}$$

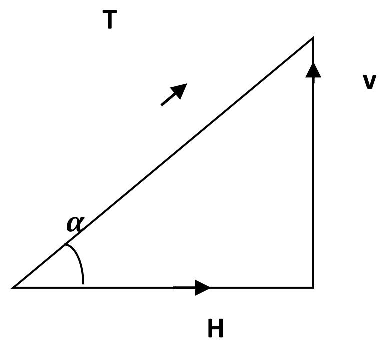
Therefore,

$$\mathbf{y = \frac{H}{w} \left(Cosh \frac{w}{H} x - 1 \right)} \qquad (8)$$

From equation (1),

$$\frac{dy}{dx} = \frac{V}{H} = Y'$$

Resolving the forces at the departure point between the sea floor and the catenary, the following right-angles triangle can be generated:



From the above triangle, $\boldsymbol{Tan\ \alpha = \frac{V}{H}}$

Therefore,

$$\frac{dy}{dx} = \frac{V}{H} = Tan\ \alpha \qquad (9)$$

From equation (8),

$$y = \frac{H}{w}\left[cosh\frac{w}{H}x - 1\right]$$

Therefore, $$\frac{dy}{dx} = \frac{H}{W} \cdot \left[\frac{W}{H} \cdot sinh\ \frac{W}{H}x\right] = sinh\ \frac{W}{H}x \qquad (10)$$

Since equations (9) and (10) are related, then,

$$Tan \propto = sinh\ \frac{W}{H}x$$

This implies that $\frac{W}{H}x = sinh^{-1}(tan \propto)$

Therefore, $$x = \frac{H}{W}sinh^{-1}(tan \propto) \qquad (11)$$

5.10 Static Analysis of catenary Cable

The static analysis of a typical catenary cable is presented below:

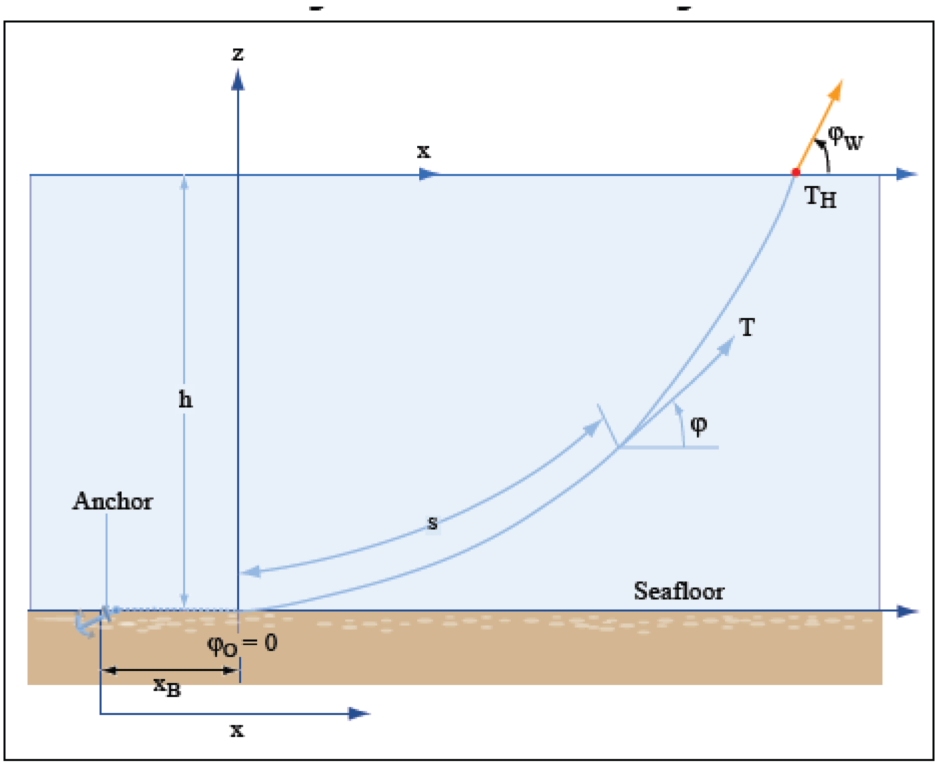


Fig 5.2 Catenary cable configuration (Source: Image by MIT Open Courseware)

Catenary cable configuration

$$S = \frac{Th}{\omega}\sinh\left(\frac{\omega}{Th}x\right)$$

$$Z+h = \frac{Th}{\omega}\left[cosh\left(\frac{\omega}{Th}x\right) - 1\right]$$

Tension along the cable:

$$T = T_h + \omega h + (\omega + \rho g A)z$$

$$T_z = \omega s$$

Catenary Solution

Minimum line length required (or suspended length for a given fair lead tension) for suction anchors:

$$l_{min} = h\left(\frac{2Tmax}{wh} - 1\right)^{1/2}$$

Horizontal force for a given fairlead tension:

$$T_{h = T - wh}$$

Horizontal scope (length in plan view from fairlead to touch down point):

$$X = = \frac{Th}{\omega}\sinh^{-1}\left(\frac{\omega lmin}{Th}\right)$$

Vertical force at fairlead:

$$Tz = wl_{min}$$

Cable load excursion relation

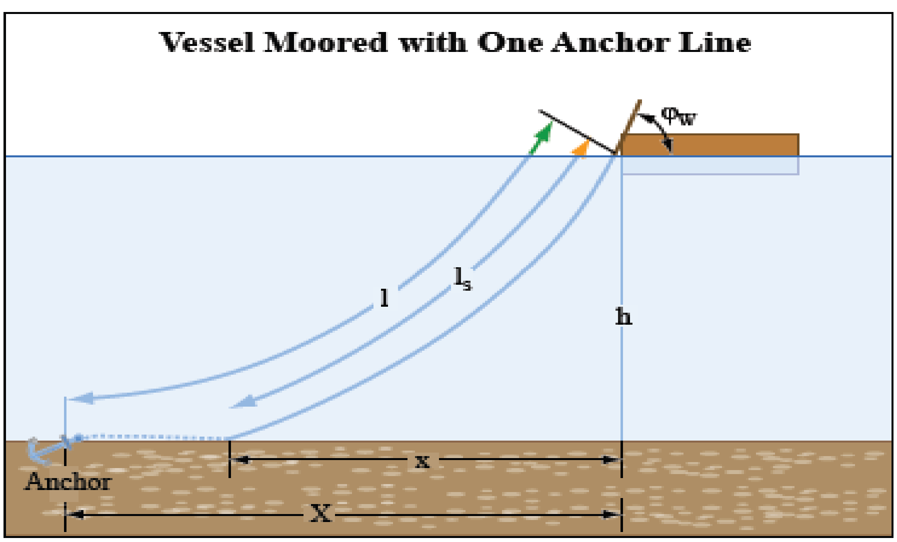


Fig 5.3 Vessel moored with one anchor line (Source: Image by MIT Open Courseware)

From Fig. 5.3, $X = l - l_s + x$

$$\text{Therefore,}\quad X + l - h\left(1 + 2\frac{Th}{\omega h}\right)^{1/2} + \frac{Th}{\omega}cosh^{-1}\left(1 + \frac{Th}{\omega h}\right)$$

Restoring Coefficient **C_{11}**

$$= \frac{dTh}{dX} = w\left(\frac{-2}{\left(1 + 2\frac{Th}{\omega h}\right)1/2} + cosh - 1\left(1 + \frac{Th}{\omega h}\right)\right)^{-1}$$

(MIT, 2011)

5.11 Catenary Solution with Elasticity

Horizontal force for a given fairlead tension:

$$T_h - AE\sqrt{\left(\frac{T}{AE} + 1\right)^2 - \frac{2wh}{AE}} - AE$$

Minimum line length required (or suspended length for a given fairlead tension) for gravity anchor:

$$l_{min} = \frac{1}{w}\sqrt{T^2 - Th^2}$$

Vertical force at the fairlead:

$$T_z = wl_{min}$$

Horizontal scope (length in the plan view from fairlead to touchdown point):

$$X = \frac{Th}{\omega}\sinh^{-1}\frac{wlmin}{Th} + \frac{Th\ lmin}{AE}$$

AE = Stiffness of the cable

5.11 Analysis of Spread Mooring Systems

The analysis of a spread mooring system is presented below:

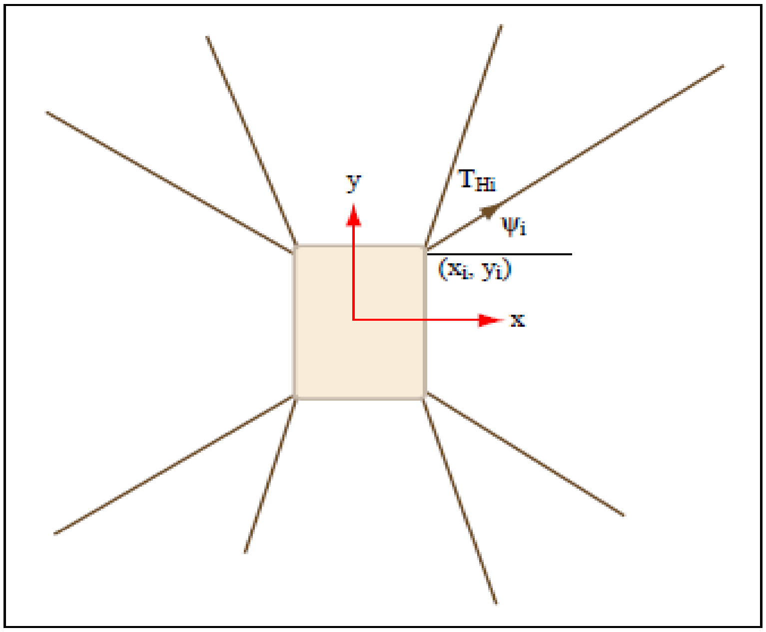


Fig 5.4 Spread mooring system (Source: Image by MIT Open Courseware)

- The mean position of body is determined by balancing force moment between those due to environment and mooring lines
- Iterative solver is usually applied

Total mooring force/moment:

$$F_1^M = \sum_{i=1}^{n} T_{Hi} \cos \Psi_i$$

$$F_2^M = \sum_{i=1}^{n} T_{Hi} \sin \Psi_i$$

$$F_6^M = \sum_{i=1}^{n} T_{Hi} \ (x_i \sin \Psi_i - y_i \cos \Psi_i)$$

Total mooring line restoring coefficient:

$$C_{11} = \sum_{i=1}^{n} Ki \ cos^2 \Psi_i$$

$$C_{22} = \sum_{i=1}^{n} Ki \ sin^2 \Psi_i$$

$$C_{66} = \sum_{i=1}^{n} Ki \ (x_i \sin \Psi_i - y_i \cos \Psi_i)^2$$

$$C_{26} = C_{62} = \sum_{i=1}^{n} Ki \ (x_i \sin \Psi_i - y_i \cos \Psi_i) \sin \Psi_i$$

(MIT, 2011)

A safety length is usually added to the minimum line length l_{min}. The safety length is also resting on the seafloor and it is a factor depending on the type of mooring line used. The safety length is typically 200-300m for wire rope mooring lines and 50-100m for chains. The extra length takes care of any risk associated with the application of vertical forces to the anchor and also, it contributes to the holding power of the anchoring system by inducing more friction by the mooring line on the seafloor.

5.12 Riser consideration in mooring analysis

The riser system interacts with the vessel and the mooring in several aspects. Wave and current loads on the risers increase the environmental loads to be resisted by the mooring, while the riser system stiffness provides assistance to the mooring. (API RP 2SK, 2005), states that; damping from the riser system decreases the low frequency motions and in turn reduces the mooring load. The net result of these effects depends on a number of factors such as type and number of risers and water depth, etc. Mooring design should take into consideration the riser loads, stiffness, inertia, and damping unless it can be demonstrated that neglecting some or all riser effects will result in same or more conservative mooring design.

Some of the floating production units are equipped with steel catenary risers or mid-water flowlines arranged in asymmetric patterns, which may impose large riser or flowline loads on the mooring system. In this ease the riser or flowline loads should be carefully evaluated and properly accounted for (API RP 2 SK, 2005).

CHAPTER SIX

RESULTS AND DISCUSSIONS

6.0 Overview

OrcaFlex was used to perform dynamic analysis on different mooring systems configurations. The results are presented in this chapter. The purpose of the dynamic analysis is to:

- Calculate forces and tensions in the mooring lines based on the prevailing environmental conditions
- Determine the Maximum effective tension in the mooring lines and also quantify the mooring offset for this vessel.
- Compare the results for the different mooring configurations.

Mooring line components includes metallic and non-metallic ropes chains, links and connecting hardware. They come in all types, materials and sizes, and, consequently, their choice, which is a function of the application, life expectancy, and the restraints involved, can be cumbersome.

Water depth is a demanding requirement for mooring, and often trade-offs must be made between cost, ease of operation, and weight. The types of components that can be used are decided by environmental conditions and operational factors. For instance, in areas where biological attacks are probable, the use of fiber ropes is not feasible. Design criteria for mooring line components are also based on factors such as vessel size, environmental loads, operational constraints, availability of the line hardware, and safety. Different combination of mooring lines are used in this analysis to secure the vessel in position and the tension obtained across the arc length of each mooring line is presented in the results.

The main components of a mooring system may consist of

- Chain, wire or rope or their combination
- Anchor or piles
- Fairleads, bending shoes or pad eyes
- Winches, chain jacks or windlasses
- Power supplies
- Rigging(e.g. stoppers, blocks, shackles)

Different combination of mooring lines are used in this analysis to secure the vessel in position and the tension obtained across the arc length of each mooring line is presented in the results. The results of the dynamic analysis can be used to determine the design criteria for a range of mooring/anchoring systems for different offshore vessels. Five mooring design cases are analyzed in this thesis. The different results generated by OrcaFlex are presented in the next section.

6.1 OrcaFlex results

The three major results generated by the OrcaFlex software after the dynamic analysis. The three important results are:

- Time history results
- X-Y Graph
- Range graphs result

6.1.1 Time history results

The time history results show a plot of the tension in the mooring lines against the period of simulation. OrcaFlex software used statistics for the maximum effective tension in the mooring lines to find the time of the greatest tension before the time history was plotted in order to select values on the vertical axis.

6.1.2 X-Y Graph

The X-Y graph shows the vessel excursion envelope. The initial slow drift as a result of the vessel's exclusion from static analysis is clearly presented in the X-Y graphs (OrcaFlex Manual).

6.1.3 Range Graphs

The range graph is the most important result generated from the OrcaFlex dynamic analysis. It shows a plot of the effective tension in each segment of the mooring lines against the arc length of the mooring lines. From the range graph, we can deduce what part of the mooring line is subjected to the maximum tension. Also, from the range graph, we can see the minimum, maximum and mean effective tension in the mooring line for the whole simulation.

6.2 Mooring System Design

Three mooring configuration cases were considered in this thesis. Dynamic analysis was performed for each mooring design case and the results are discussed herein. The three cases are:

- Case 1- (Chain-Fiber rope- Chain)
- Case 2- (Wire rope-Chain)
- Case 3- (Chain-Wire rope- Chain)

6.2.1 Case 1

In case 1, an offshore vessel is moored with eight symmetric mooring lines spaced 45° apart. The mooring lines comprise chain and Polyester fiber rope. The mooring geometry is a catenary mooring system. The simulation uses regular waves acting on the vessel for the duration of 115 seconds. The mooring system employs a turret, located at the vessel's moonpool. Since all mooring lines are connected to the turret, the vessel is free to rotate about the turret-wellhead axis and head into oncoming seas, regardless of direction. Thrusters are provided at the bow and stern to assist in maintaining a desired heading. The chain table connecting the mooring line to the turret is above the waterline. The wave theory used in the analysis is Dean Stream. The function is explained in section 6.2.1.2. The vessel is 103m long. This is the default length of the vessel used with the associated RAO's used for OrcaFlex calculations. . The vessel weighs 8800 tonnes

6.2.1.1 RAOs

OrcaFlex uses two different types of RAO (response amplitude operator): **Displacement RAOs** and **Wave Load RAOs**.

Displacement RAOs are specified on the **Displacement RAOs** page on the vessel type data form. They define the 1st order motion of the vessel in response to waves of given period and amplitude. They are only used if the vessel superimposed motion is set to RAOs + Harmonic. In the dynamic analysis the vessel moves harmonically, in all 6 degrees of freedom, about its primary position. These harmonic motions are specified by giving the RAO amplitudes and phases, for all six degrees of freedom, usually for a range of wave periods and directions. For further information see RAOs and Phases.

Wave load RAOs are specified on the **Load RAOs** page on the vessel type data form. They define the 1st order wave force and moment on the vessel due to waves of given period and amplitude. They are only used if the 1st order wave loads are included for the vessel and they only affect the motion if the vessel primary motion is set to one of the calculated options (OrcaFlex Manual, 2011). The RAO's are presented in Appendix 1.

The Turret mooring system is a proven technology that is widely used in the North Sea and other exploration and production fields worldwide. The turret mooring systems allows the vessel to weathervane 360 degrees, allowing normal operations in moderate and harsh sea conditions. This enables the offshore vessel to stay permanently on location under different environmental conditions. A screen shot of the turret mooring system taken from the OrcaFlex simulation file after the dynamic analysis is shown in Fig 6.1 below.

6.2.1.2 Dean Stream Function theory

A typical approach to wave theory makes use of the idea of a velocity potential. This is a vector field $\phi(x,z)$ whose partial derivatives are the particle velocities of the fluid. That is

$\delta\phi/\delta x = u$ and $\delta\phi/\delta z = v$.

Also the function satisfies the following equations:

1) Satisfies Laplace's equation $\delta 2\psi/\delta x2 + \delta 2\psi/\delta z2 = 0$, which means that the flow is irrotational,
2) Is zero at the seabed, that is $\psi(x,0) = 0$,
3) Is constant at the free surface $z = \eta(x)$, say $\psi(x,\eta) = -Q$ and
4) Satisfies Bernoulli's equation $½ [(\delta\psi/\delta x)2 + (\delta\psi/\delta z)2] + \eta = R$, where R is a constant.

In these equations all variables have been non-dimensionalised with respect to water depth d and gravity g.

By standard methods, equations (1) and (2) are satisfied by a stream function of the form

$\psi(x,z) = B0\ z + \Sigma\ Bj\ [\sinh(jkz) / \cosh(jk)] \cos(jkx)$, where k is the wave number which is as yet undetermined, and the summation is from j = 1 to N. The constant N is said to be the **order** of the stream function. The problem now is to find coefficients Bj and k which satisfy equations (3) and (4).

6.2.1.3 Accuracy of Dean Stream function

Because the method is a numerical best fit method it does not suffer from the truncation problems of the Stokes' 5th and other deep water wave theories. For these methods, power series expansions are obtained and then truncated at an arbitrary point. If the terms which are being ignored are not small then these methods will give inaccurate answers. In theory, Dean's method should cope well in similar circumstances as it is finding a best fit to the governing equations. This means that stream function wave theory is very robust (OrcaFlex Manual, 2011).

In the model, the turret is represented by an elastic solid body, cylindrical in shape which is placed within the hull, in a moonpool. The chain is drawn as yellow in the model and the polyester fiber ropes are drawn blue. The water depth is 500m and the regular wave theory used in the analysis is Dean Stream. The mechanical properties of the chain and fiber rope used in this analysis are shown in table 6.2 and 6.3 respectively. It is mandatory to design mooring systems to be able to withstand different combinations of environmental forces (wind, waves and currents) yielding the same return period of 100 years in conformity with regulations and standards such as API RP 2SK, and DNV-RP-E301. The prevailing environmental condition is obtainable in South China Sea. Environmental data are presented in Table 6.1.

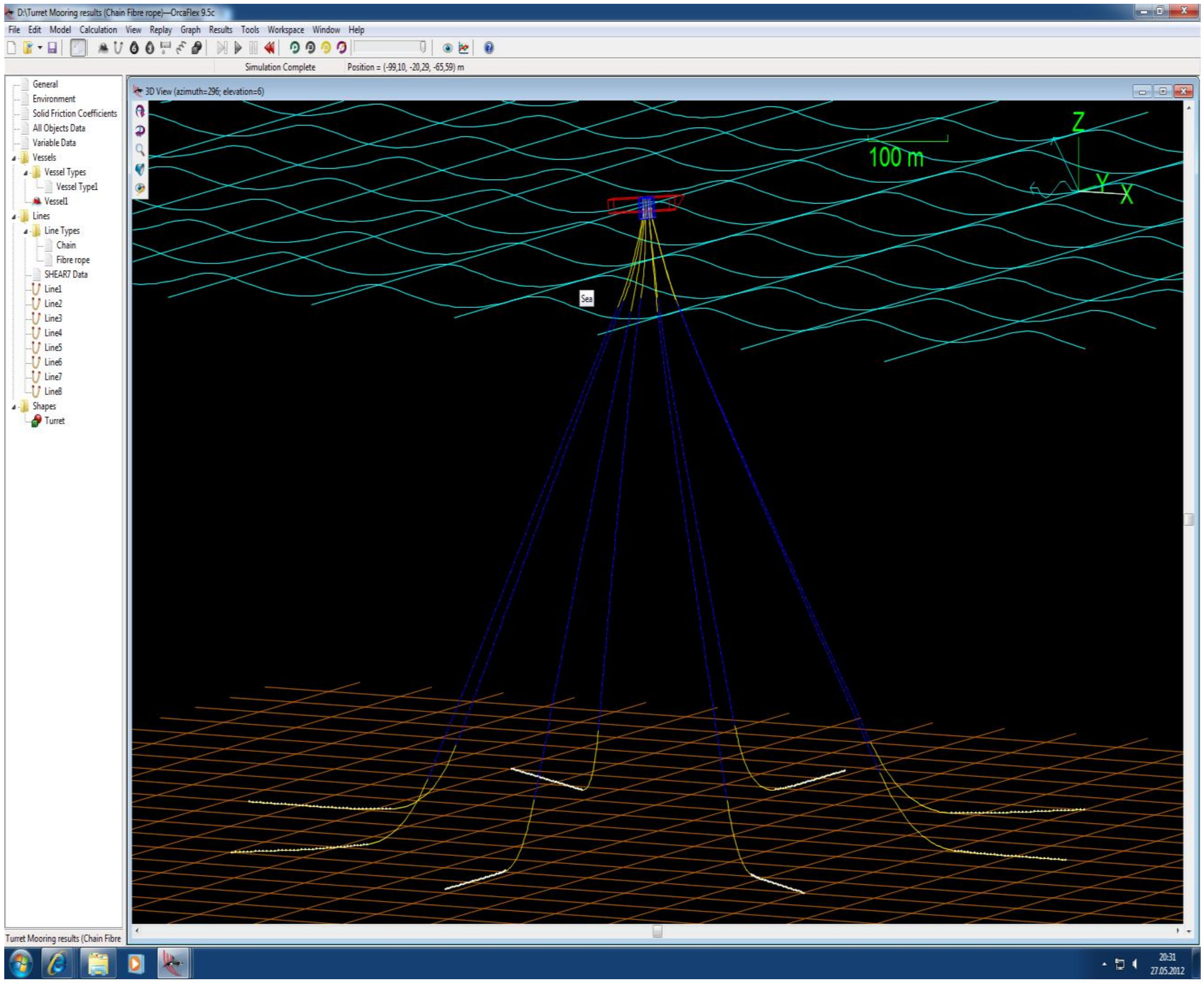


Fig 6.1 Turret moored offshore vessel (Chain and Fiber rope mooring line) Case 1

The eight 900m long mooring lines are composed of chain (100m), fiber rope (500m) and chain (300m) respectively. The mooring line structure is selected so as to reduce the weight of the mooring lines and consequently reducing the maximum effective tension.

Furthermore, fiber rope increases the flexibility of the mooring lines. In a chain/fiber rope mooring configuration, a length of chain is typically connected to the anchor. This provides good abrasion resistance where the mooring line contacts the seabed and its weight contributes to the anchor holding capacity. The choice of chain or fiber rope at the vessel end and the type of termination also depends on the requirements for adjustment of line tensions during operations (API RP 2SK, 2005). The selected combination system offers the advantages of reduced pretension requirements with higher restoring force, improved anchor holding capacity, and good resistance against bottom abrasion. These advantages make the combination system attractive for deep water mooring.

Table 6.1 Environmental data (Case 1)

WAVE DATA	
Wave type (Regular wave)	Dean Stream
Wave height (m) (Regular wave)	16.0
Wave period (s)	11.5
Wave direction (deg)	180.0
Wave length (m)	228.0449
Wave number (rad/m)	0.0276
Ursell number	0.0039
Breaking wave height (m)	28.9094

Table 6.2 Properties of Chain for Case 1

CHAIN PROPERTIES	
Outer Diameter (m)	0.094
Inner Diameter (m)	0
Bulk Modulus	Infinity
Weight in air (te/m)	0.055
Poisson ratio	0.5
Weight in water(te/m)	0,048
Displacement (te/m)	0,0072
Diameter/Weight Ratio	1,987m/(te/m)
Bending stiffness $KN.m^2$	-
Axial stiffness $KN.m^2$	252500
Minimum Breaking Load (KN)	2740
Torsional stiffness $KN.m^2$	80

Table 6.3 Properties of Fiber rope for Case 1

FIBER ROPE PROPERTIES	
Outer Diameter (m)	0.043
Inner Diameter (m)	0
Bulk Modulus	Infinity
Weight in Air (te/m)	0.0020
Poisson ratio	0.5
Bending stiffness (KN/m)	-
Weight in water (te/m)	0,00051
Displacement te/m)	0,0015
Diameter/Weight Ratio	84,981m/(te/m)
Axial stiffness (KN/m)	2725
Minimum Breaking Load (kN)	426.167
Torsional stiffness (kN/m)	10

6.2.2 Results (Case 1)

A range graph shows a plot of the effective tension in each segment of the mooring lines against the arc length of the mooring lines. From the range graph, we can deduce what part/segment of each mooring line is subjected to the maximum tension. Also from the range graph result, we can also see which mooring line is undergoing the maximum effective tension. The maximum effective tension in the mooring lines for case 1 is presented in Table 6.4 below. The range graph values for case 1 are given in appendix 2-A.

Table 6.4 Maximum effective tension at arc length 0m (Case 1)

Mooring lines	Direction with wave	Maximum Effective tension (kN)	Arc length
Line 1	In line with wave 0^0	142.6	0
Line 2	45^0	97.85	0
Line 3	90^0	126.56	0
Line 4	135^0	88.28	0
Line 5	180^0	102.1	0
Line 6	225^0	130.24	0
Line 7	270^0	112	0
Line 8	315^0	138.94	0

6.2.3 Discussion of results (Case 1)

From Table 6.4 above, we can clearly deduce that the maximum effective tension is highest in mooring line 1, followed by mooring line 8 and lowest in mooring line 4. The maximum tension occurs at the turret end connection to the chains. This is as a result of the vessel motions induced by environmental forces. The greatest impact is felt at the turret end of each mooring line. Fig 6.2 below shows a chart of the maximum effective tension in each mooring line and the segment of the mooring lines in which the maximum effective tension occurs.

We can also see from the results that the maximum tension obtained in the mooring lines is much lower than the minimum breaking loads of the mooring line materials, as can be seen in Table 6.2 and table 6.3. This implies that the design is adequate and the mooring system will sustain mooring loads under the prevailing environmental condition.

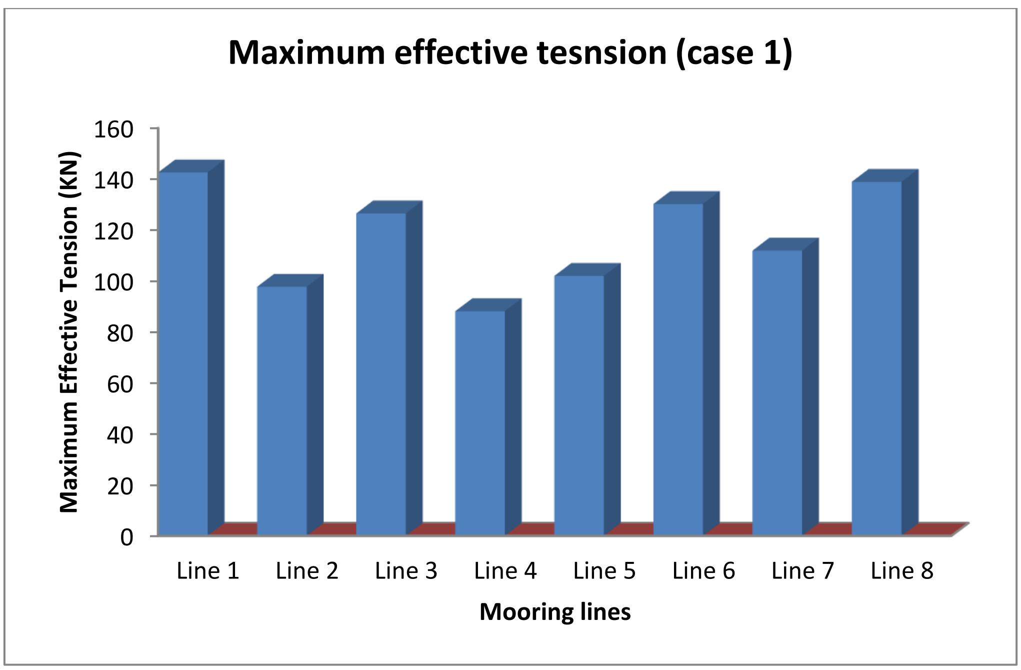


Fig 6.2 Mooring line tension (Case 1)

The end forces (Total force and vertical force) in the mooring lines are shown in Table 6.6 below. We can also see from the results that the total force is highest at mooring line 1, followed by mooring line 8 and lowest at mooring line 4 at the vessel end. Similarly, at the anchor end, the highest tension is at mooring line 1 while the lowest is at mooring line 4.

Table 6.6 Vessel end forces (Case 1)

Connections							
	Vessel End			Anchor end		Maximum Tension Segment	
	Total	Vertical	Total Force	Total	Uplift	Segment	
Connection to	Force (KN)	Force (KN)	Declination (deg)	Force (KN)	Angle (deg)	Number	Tension (KN)
Line1 End A	139.5118	138.7272	173.9205	58.1597	0.0	2	139.704
Line2 End A	96.9335	96.3435	173.6751	28.8745	0.0	2	100.3237
Line3 End A	121.7125	119.7723	169.7559	42.1313	0.0	2	122.5145
Line4 End A	82.7798	80.2244	165.7267	31.7627	0.0	2	84.1822
Line5 End A	95.7596	94.5415	170.8512	19.2898	0.0	2	98.6819
Line6 End A	128.3707	127.9946	175.6129	43.8693	0.0	A	128.1497
Line7 End A	111.5348	111.3143	176.3965	53.805	0.0	2	113.3269
Line8 End A	136.5653	136.4491	177.6361	49.7263	0.0	A	136.2031
Turret	86.2672	-0.3857	89.7438				

6.2.4 Range graph results

The range graph results for each mooring line in case 1 is shown in Fig 6.3 to Fig 6.10 below. The range graph plots enable us to see the minimum, maximum, and mean effective tension across the arc length of the mooring lines for the whole simulation. In the range graph plot, the maximum effective tension line is drawn green; the minimum effective tension line is drawn blue while the mean effective tension line is drawn brown. The large peaks for tension in Figures 6.4, 6.6 and 6.7 for mooring line 2, mooring line 4 and mooring line 7 respectively are as a result of snap loads. The tension drops and pick up suddenly resulting to very high tension in the mooring lines. The snap loads occurred at the chain section of the mooring line lying horizontally on the sea floor.

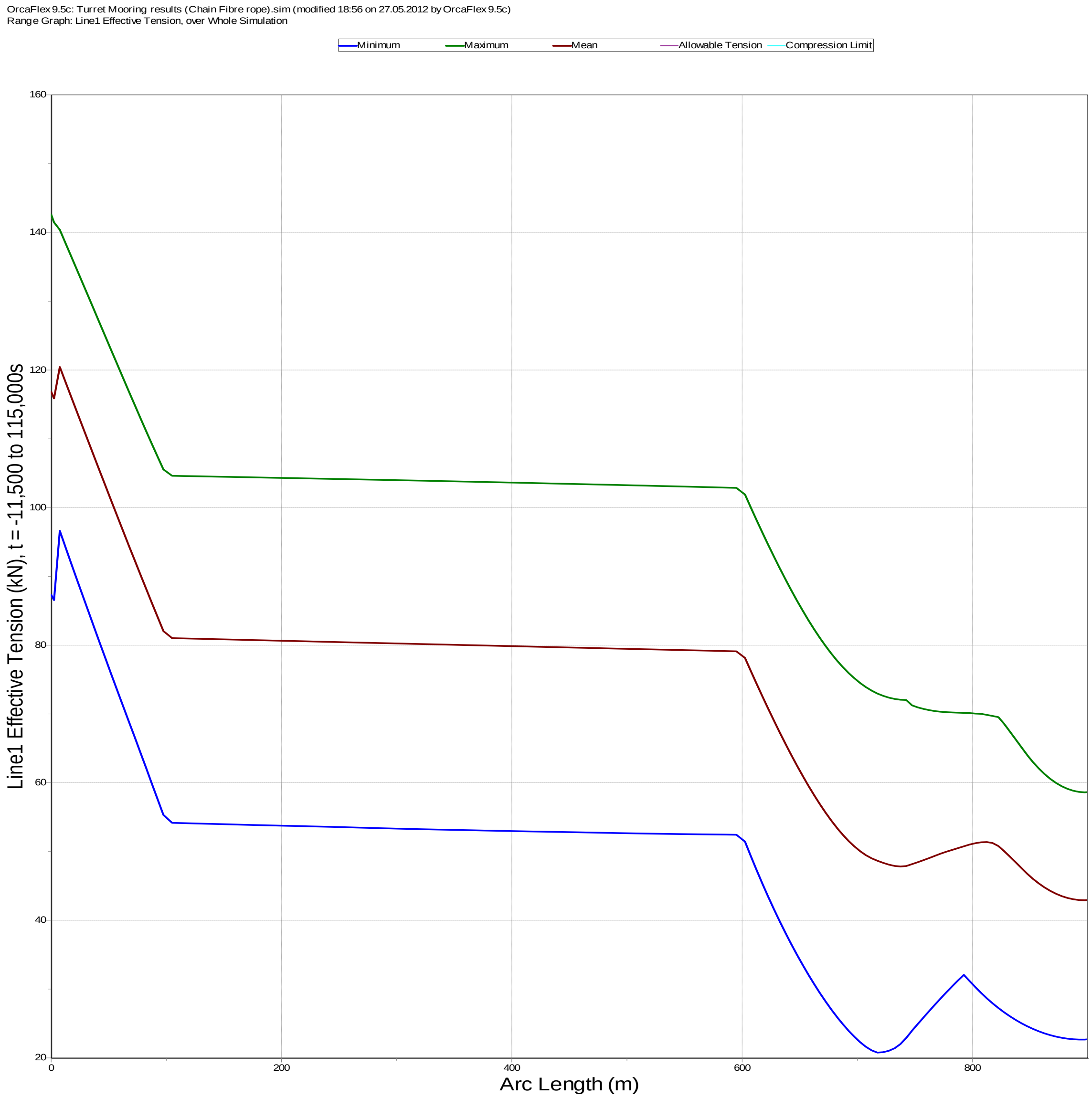


Fig 6.3 Range graph for Mooring line 1 (Case 1)

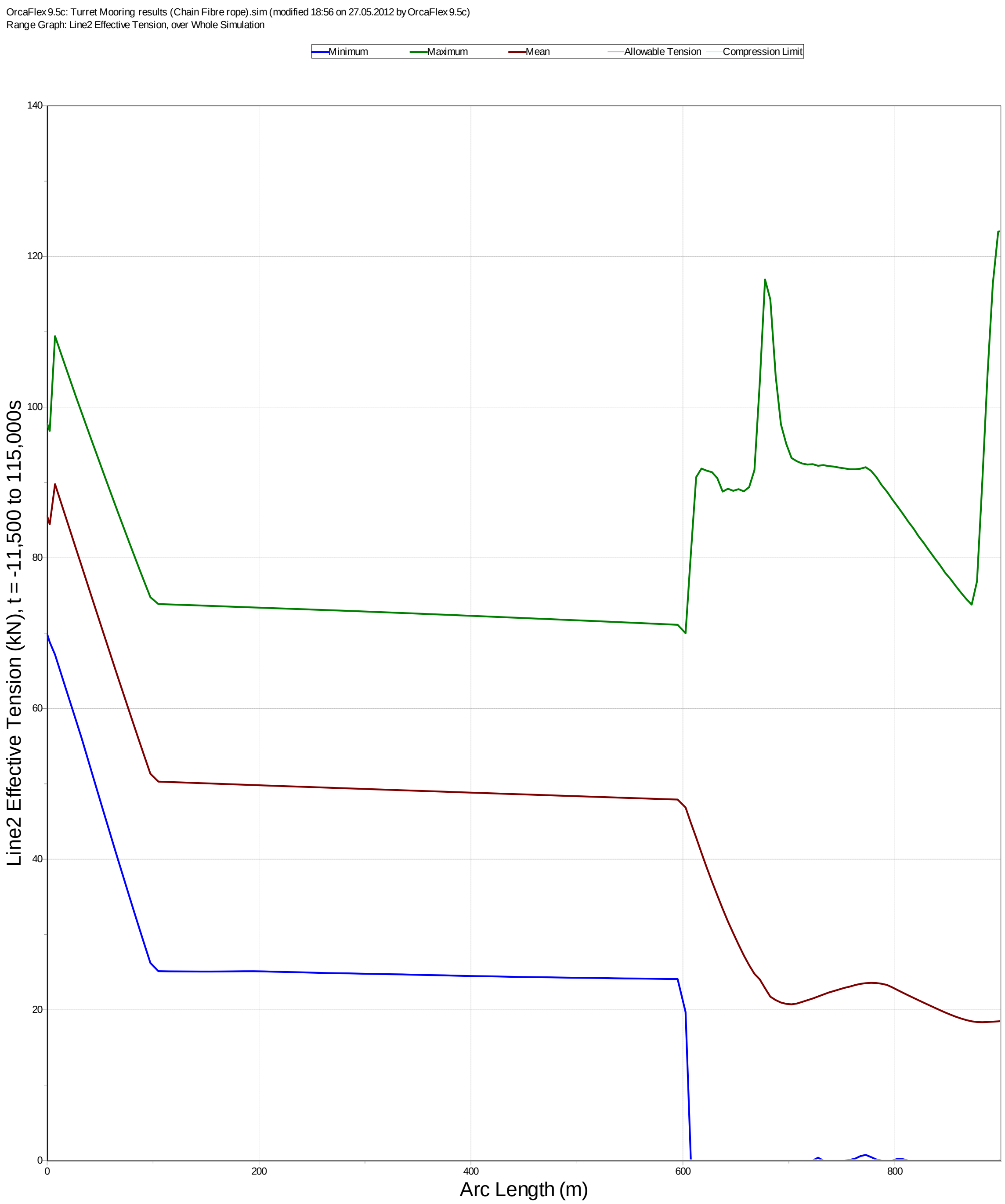


Fig 6.4 Range graph for Mooring line 2 (Case 1)

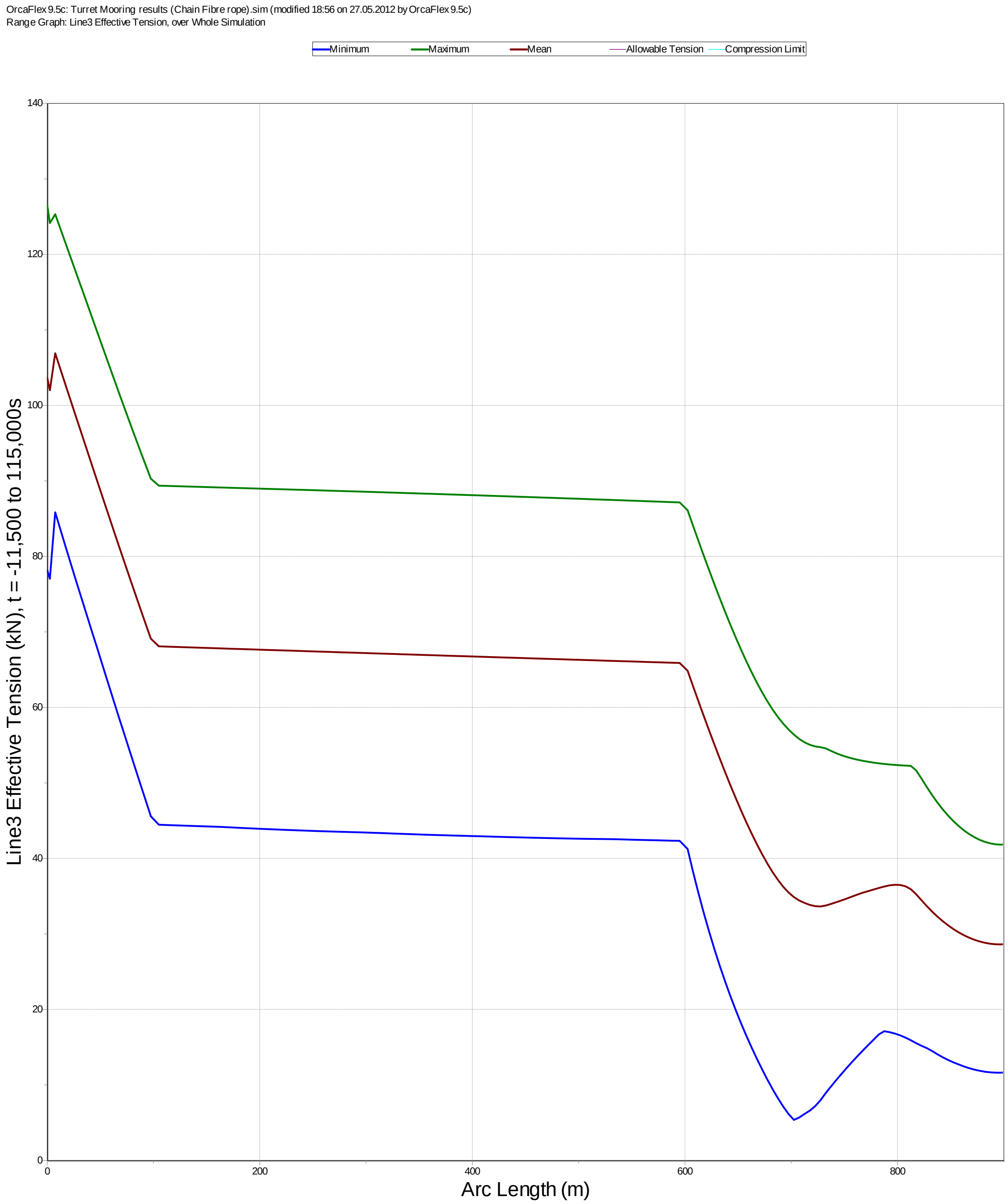


Fig 6.5 Range graph for Mooring line 3 (Case 1)

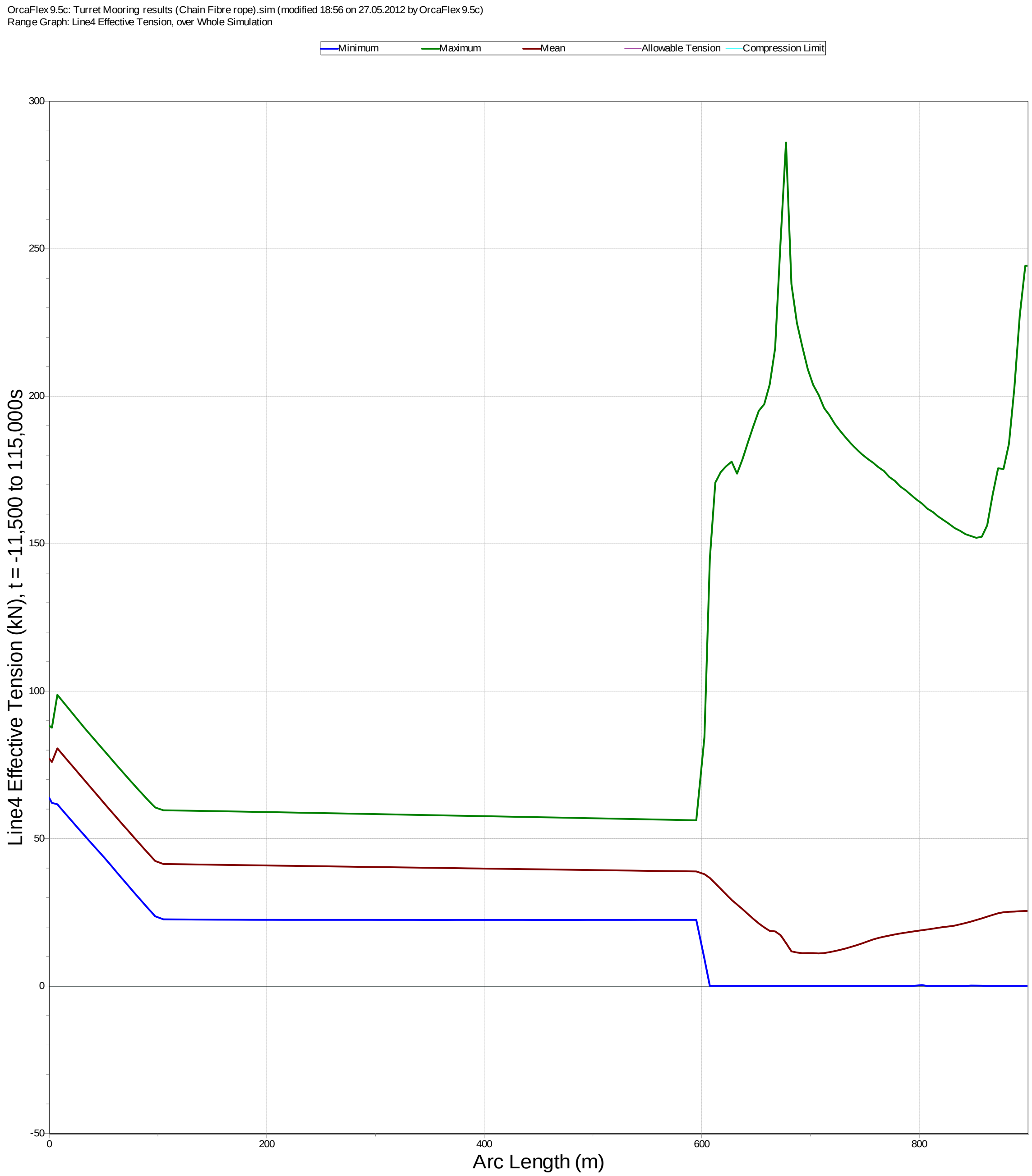


Fig 6.6 Range graph for Mooring line 4 (Case 1)

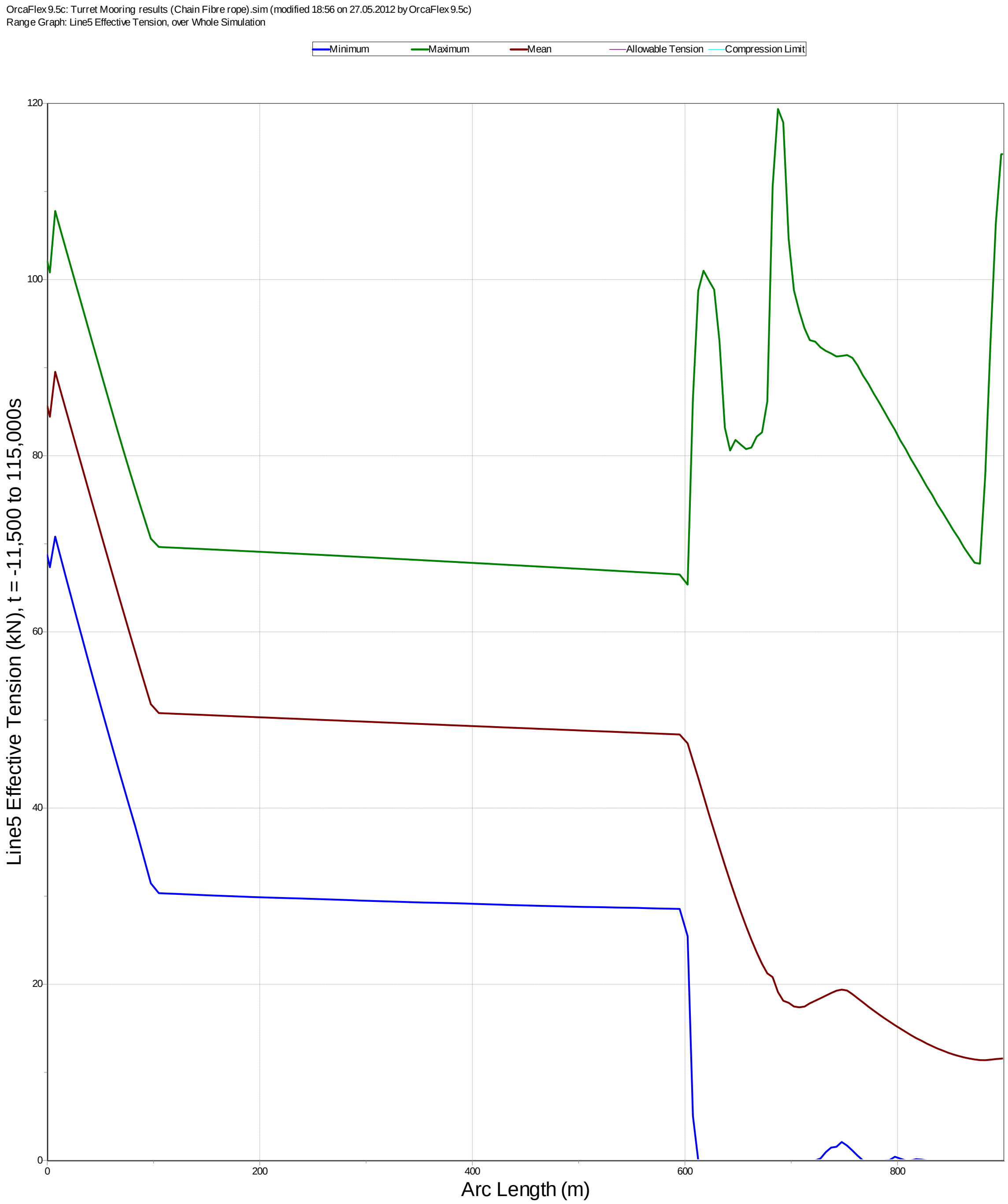


Fig 6.7 Range graph for Mooring line 5 (Case 1)

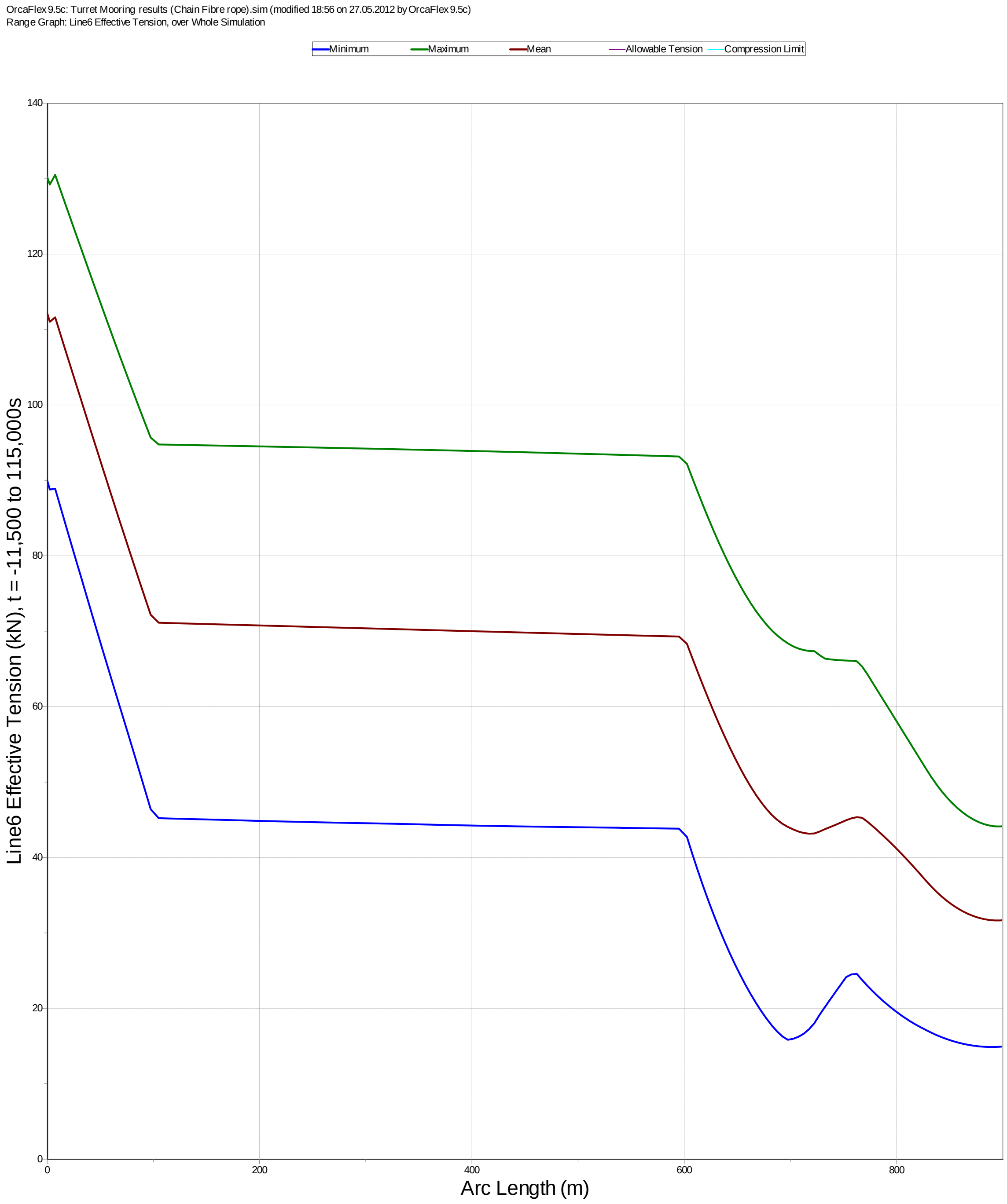


Fig 6.8 Range graph for Mooring line 6 (Case 1)

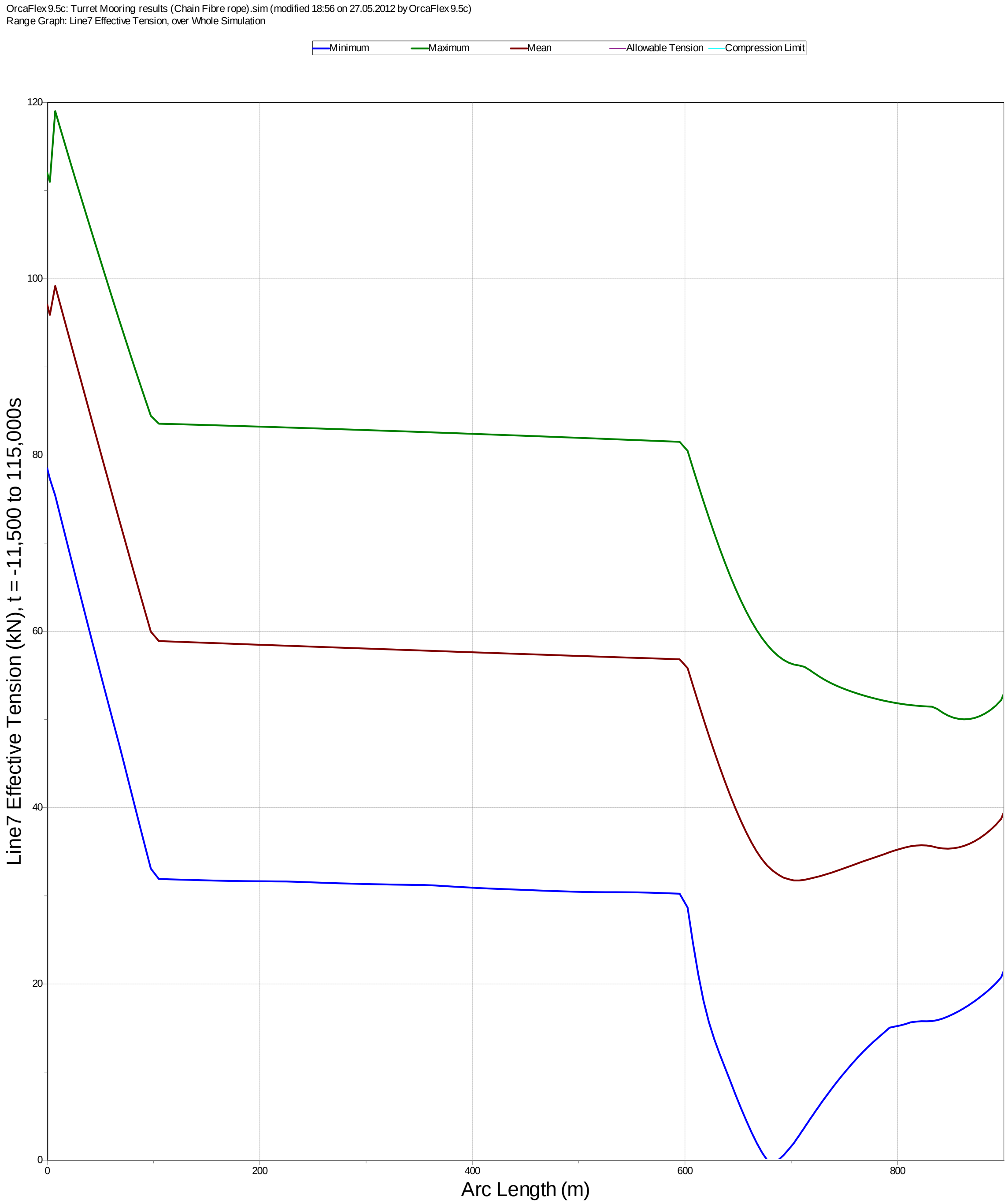


Fig 6.9 Range graph for Mooring line 7 (Case 1)

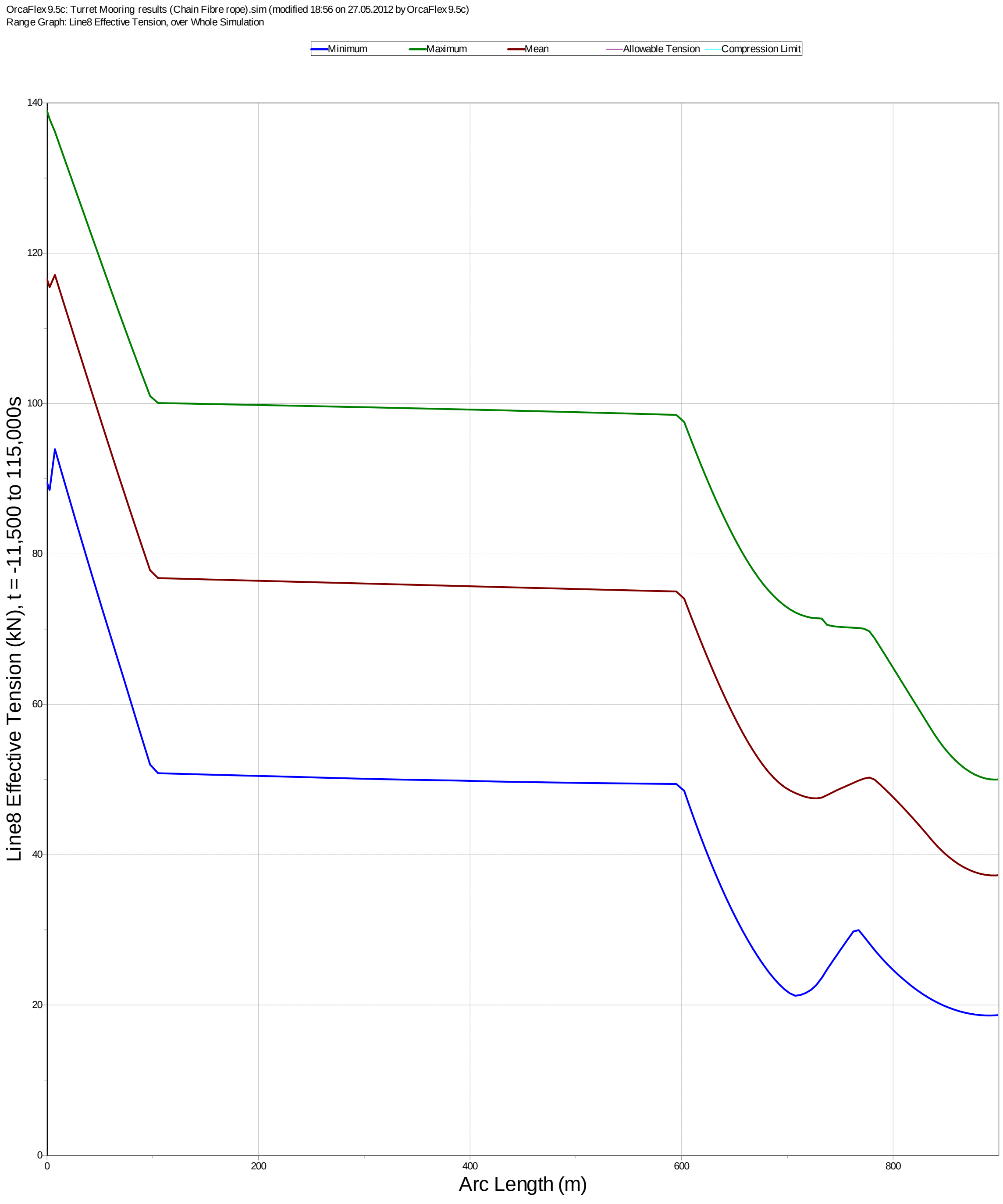


Fig 6.10 Range graph for Mooring line 8 (Case 1)

6.2.5 Time History results (Case 1)

The time history results show a plot of the sea elevation against the simulation time for the environment, and also shows the vessel elevation against the simulation time (t =11.5 -115 seconds). For the mooring lines, the time history results show a plot of the effective tension in the mooring lines against the period of simulation.

OrcaFlex software took statistics for the maximum effective tension in the mooring lines to find the time of the greatest tension. The period at which the maximum effective tension occurs in the mooring lines can be easily read from the time history plots. Fig 6.11 to Fig 6.21 below shows the time history plots for the environment, vessel and mooring lines respectively. The time history values for case 1 are given in appendix 3-A.

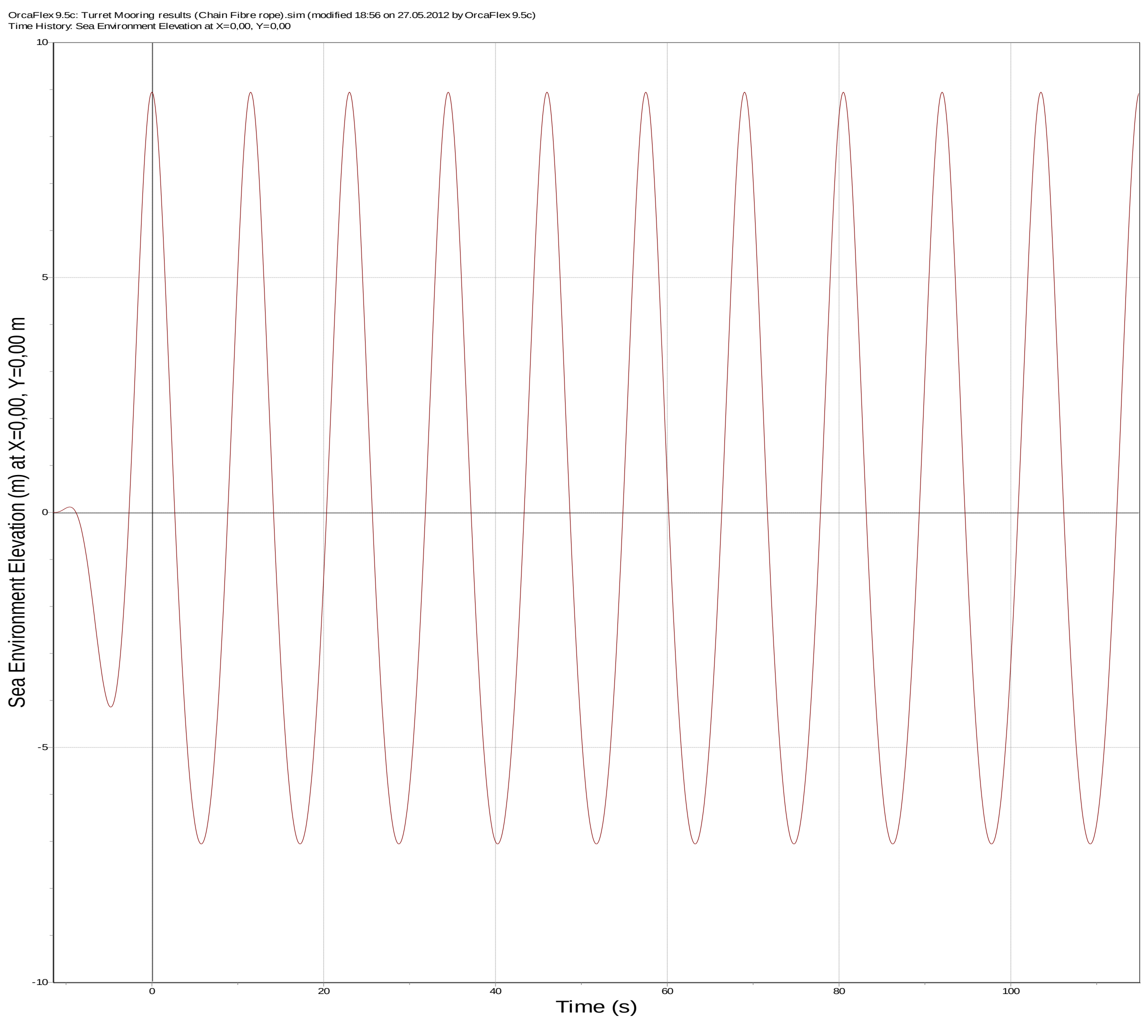


Fig 6.11 Time history results for sea environment (Case 1)

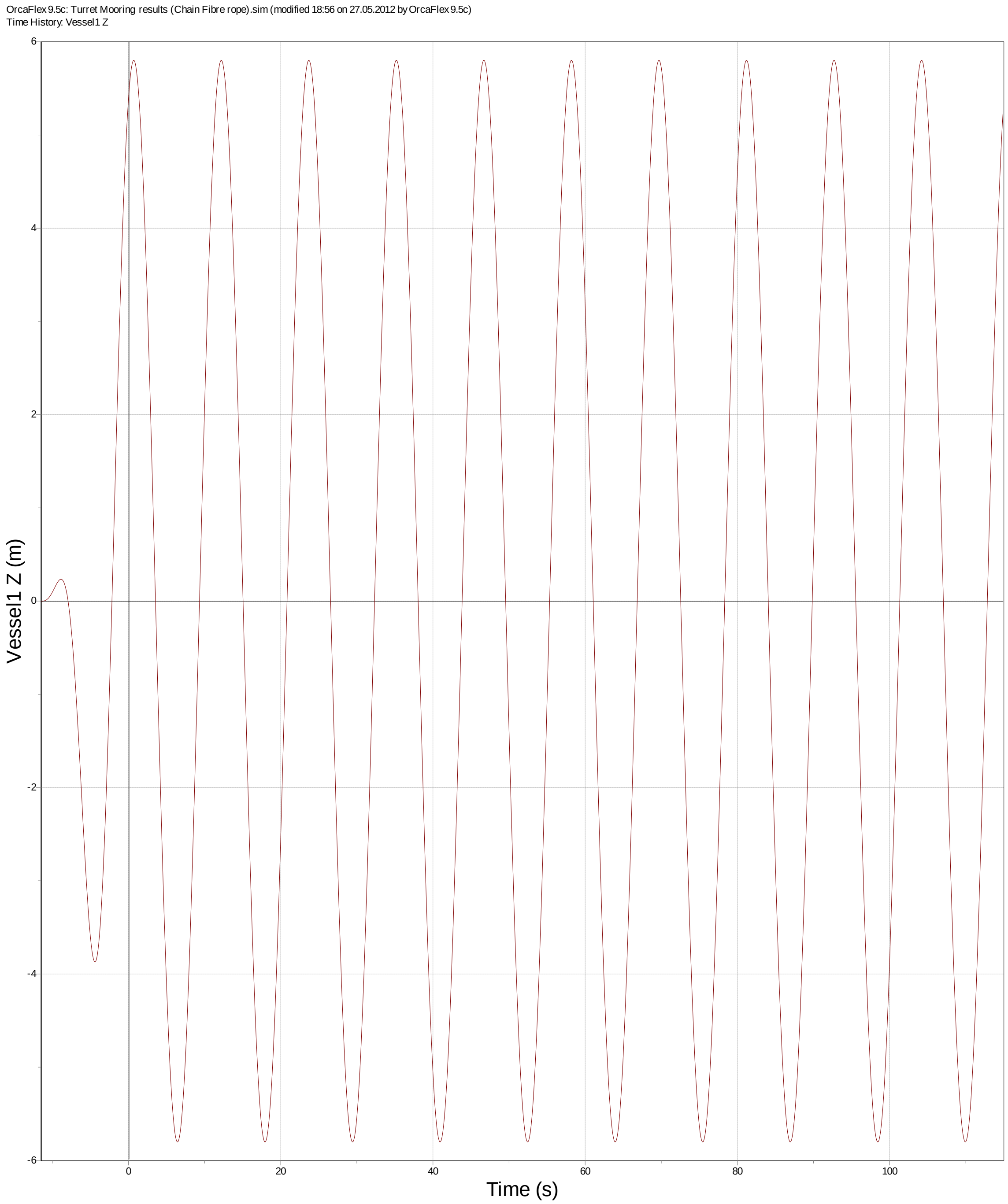


Fig 6.12 Time history results for Vessel vertical motion (heave) in Case 1

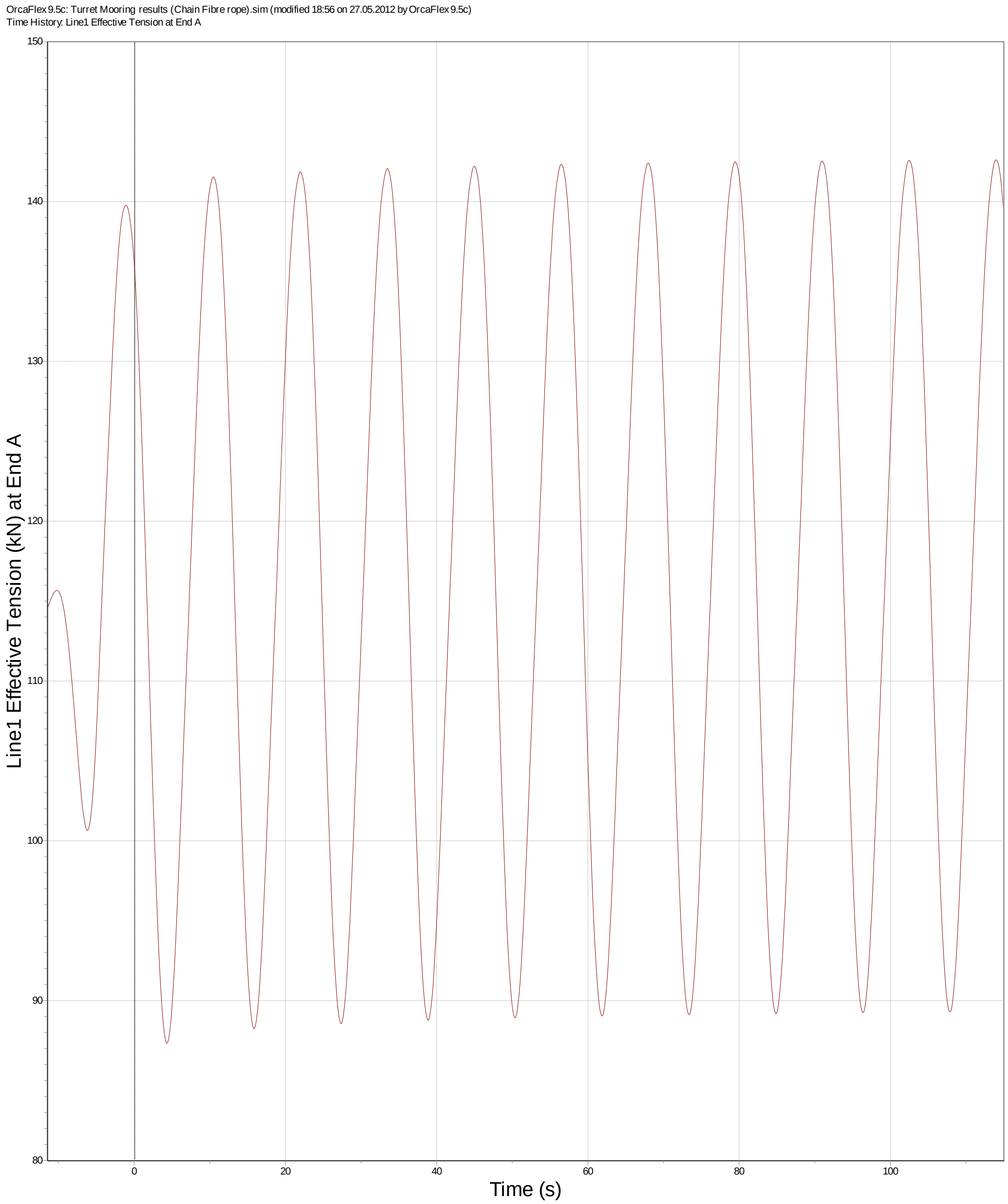


Fig 6.13 Time history results for Tension in Mooring line 1 (Case 1)

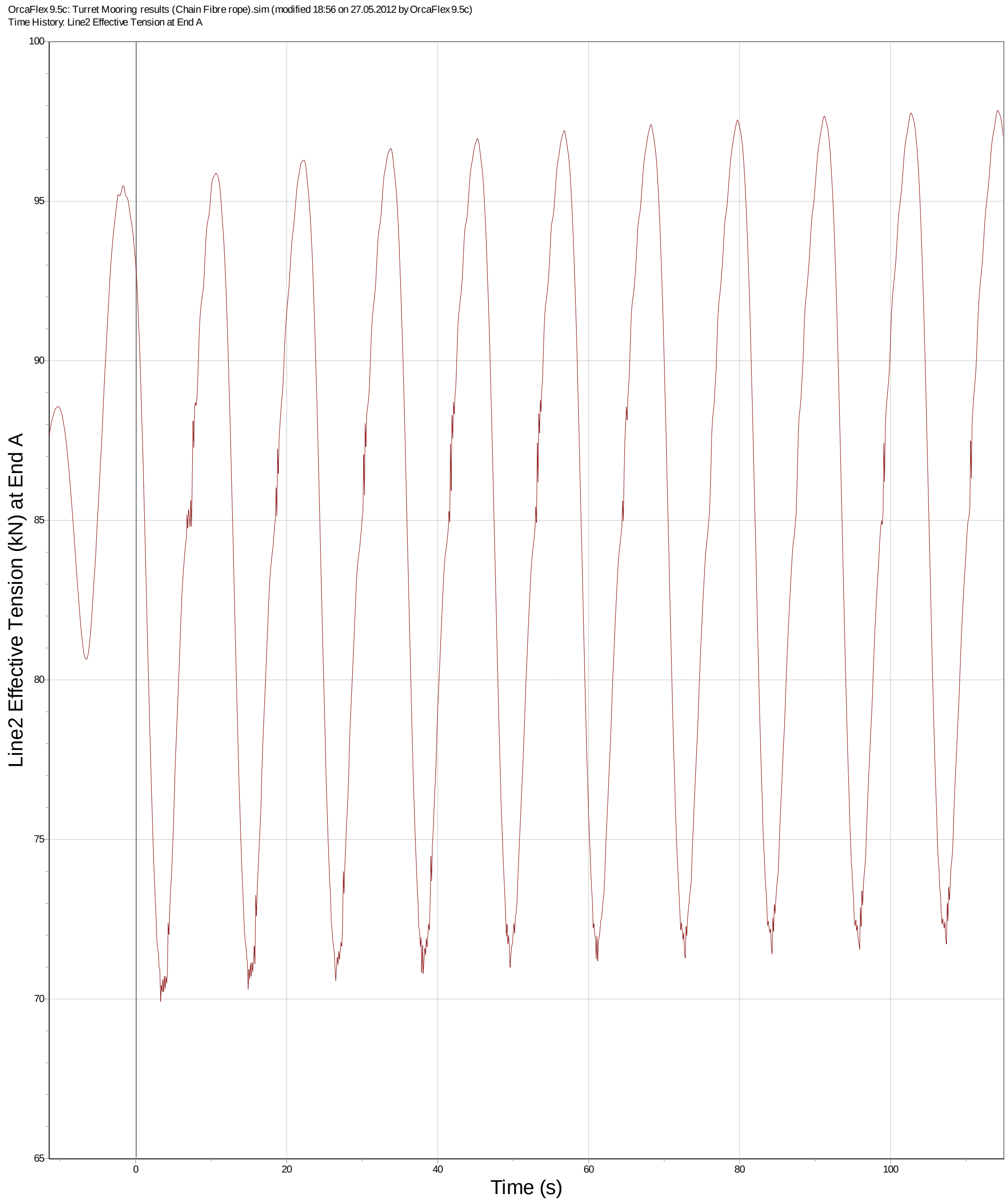


Fig 6.14 Time history results for Tension in Mooring line 2 (Case 1)

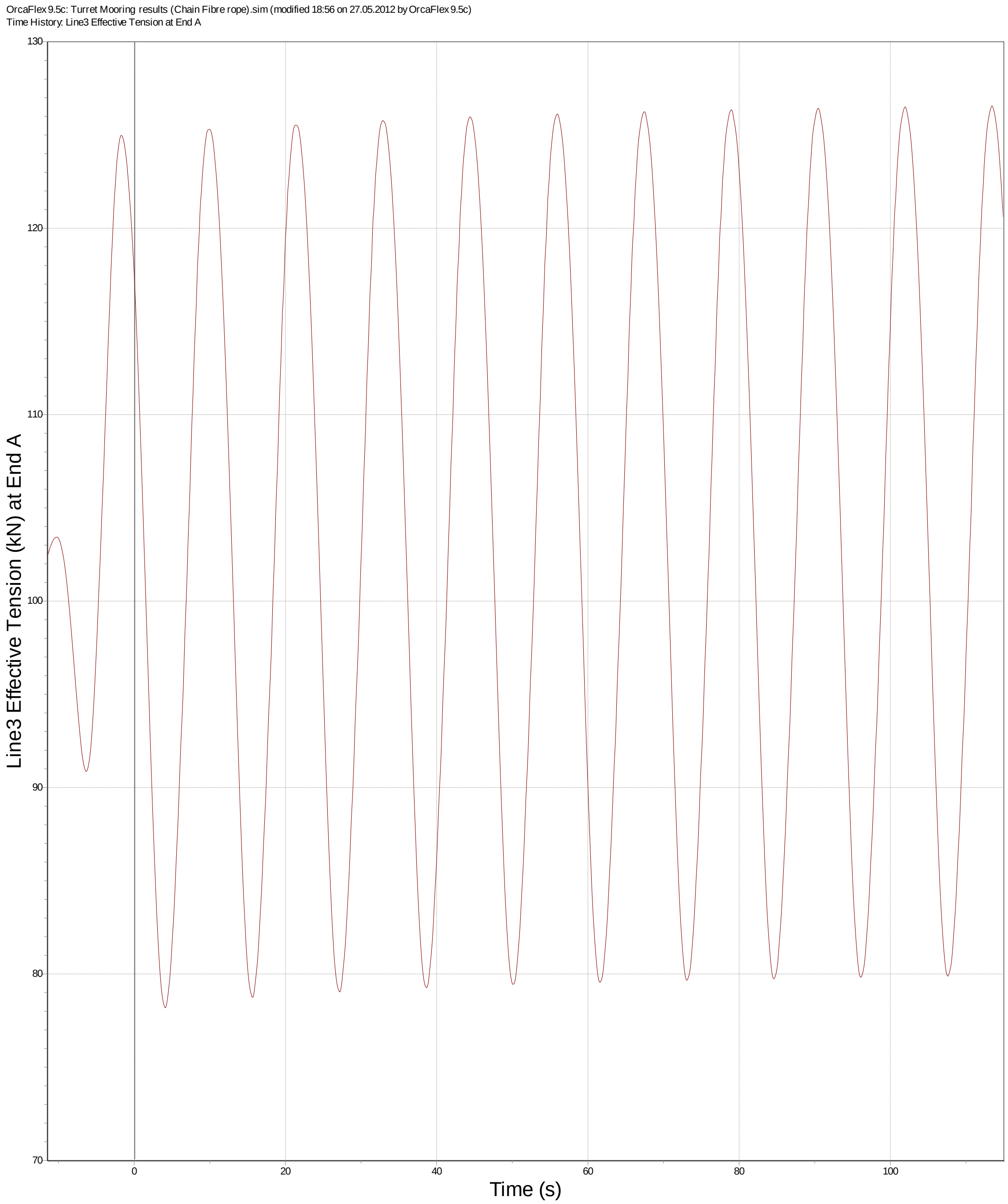


Fig 6.15 Time history results for Tension in Mooring line 3 (Case 1)

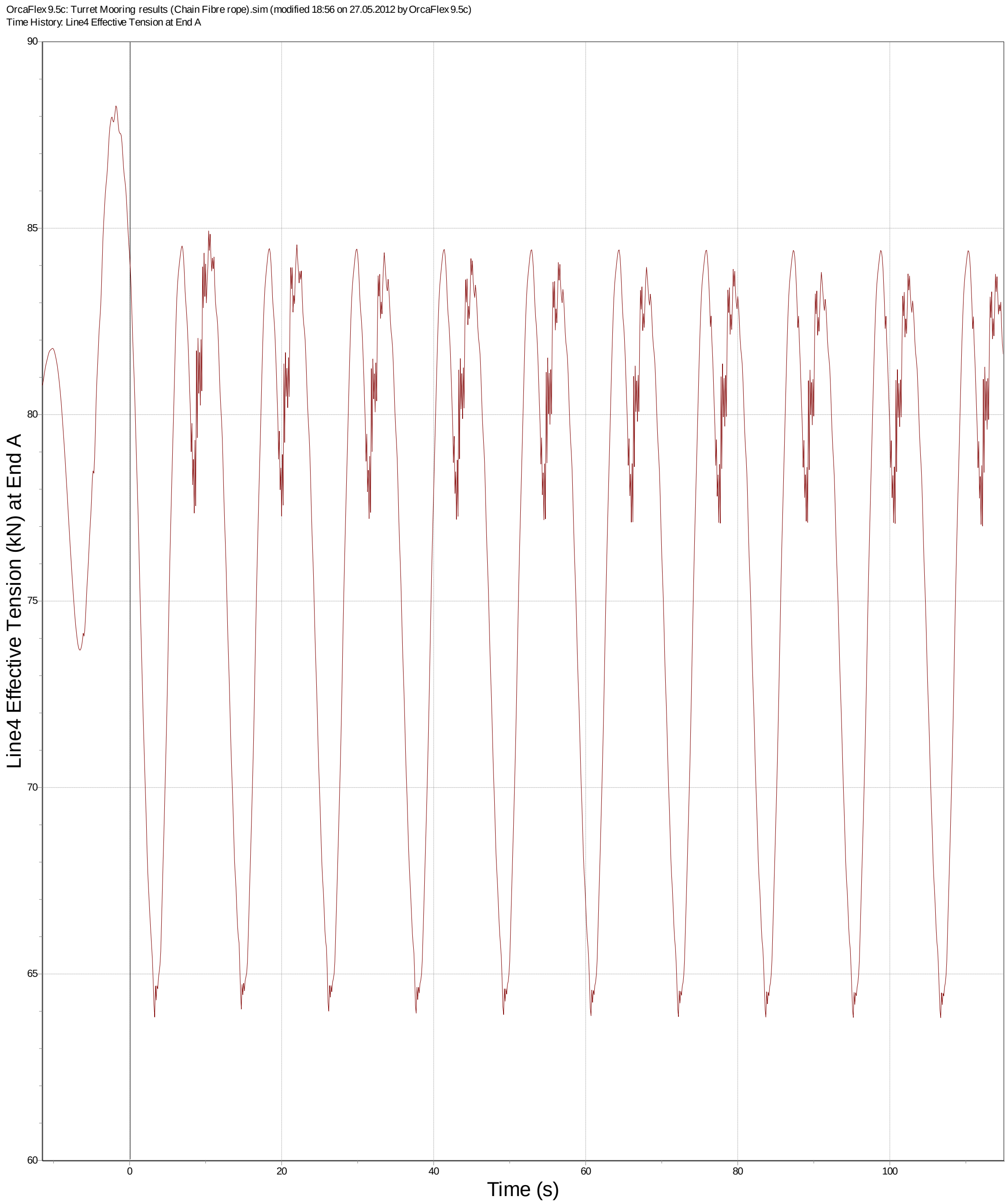


Fig 6.16 Time history results for Tension in Mooring line 4 (Case 1)

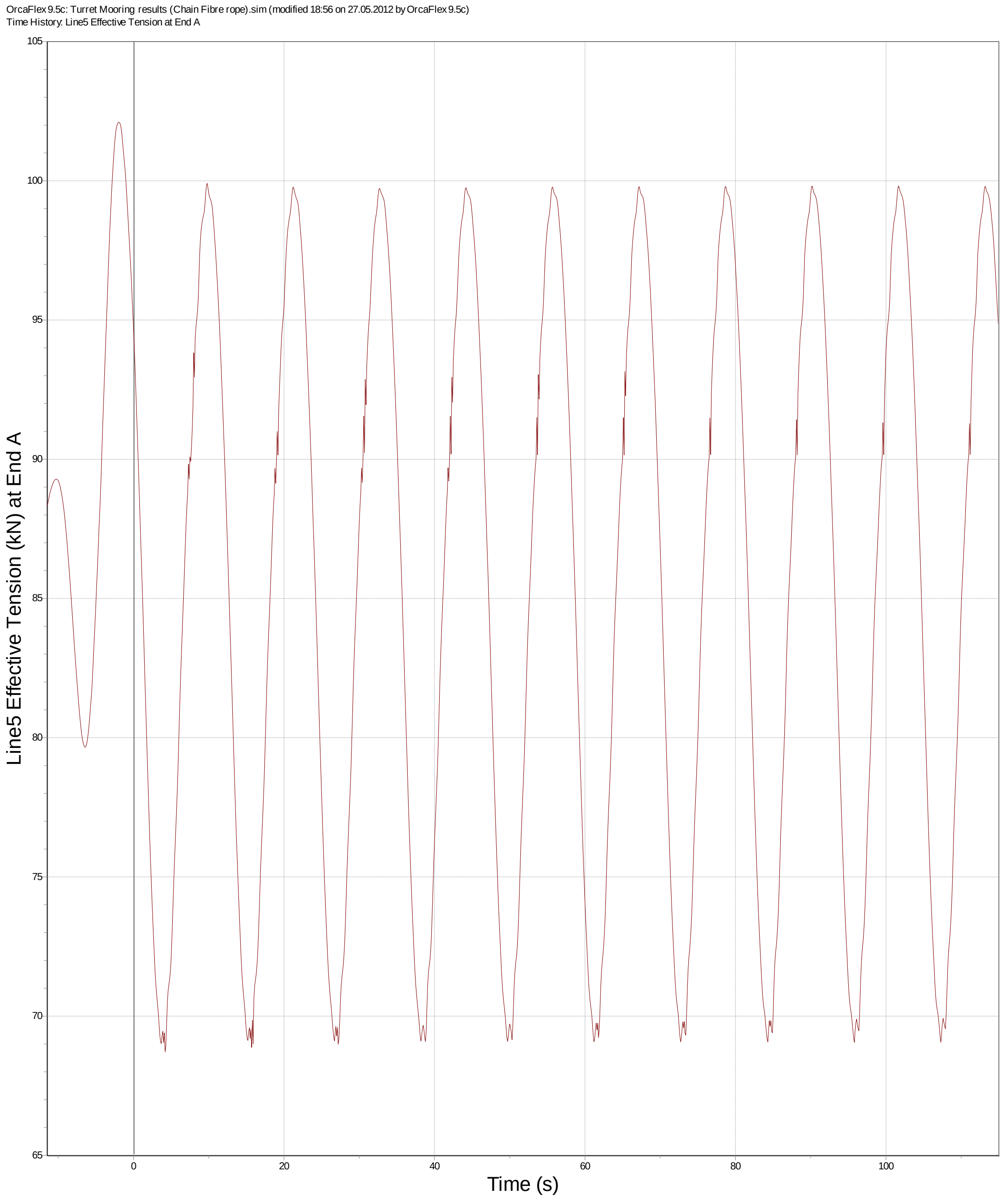


Fig 6.17 Time history results for Tension in Mooring line 5 (Case 1)

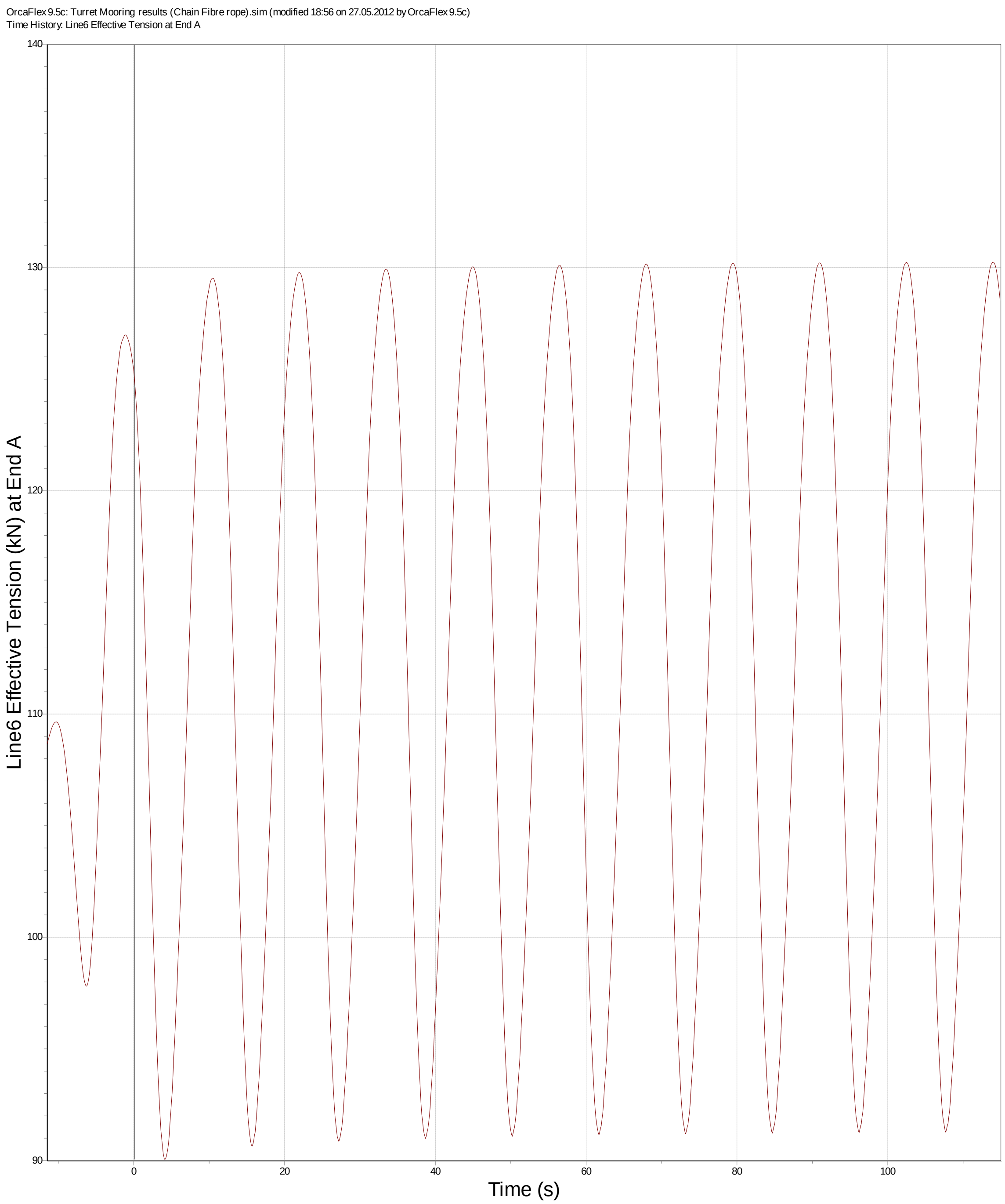


Fig 6.18 Time history results for Tension in Mooring line 6 (Case 1)

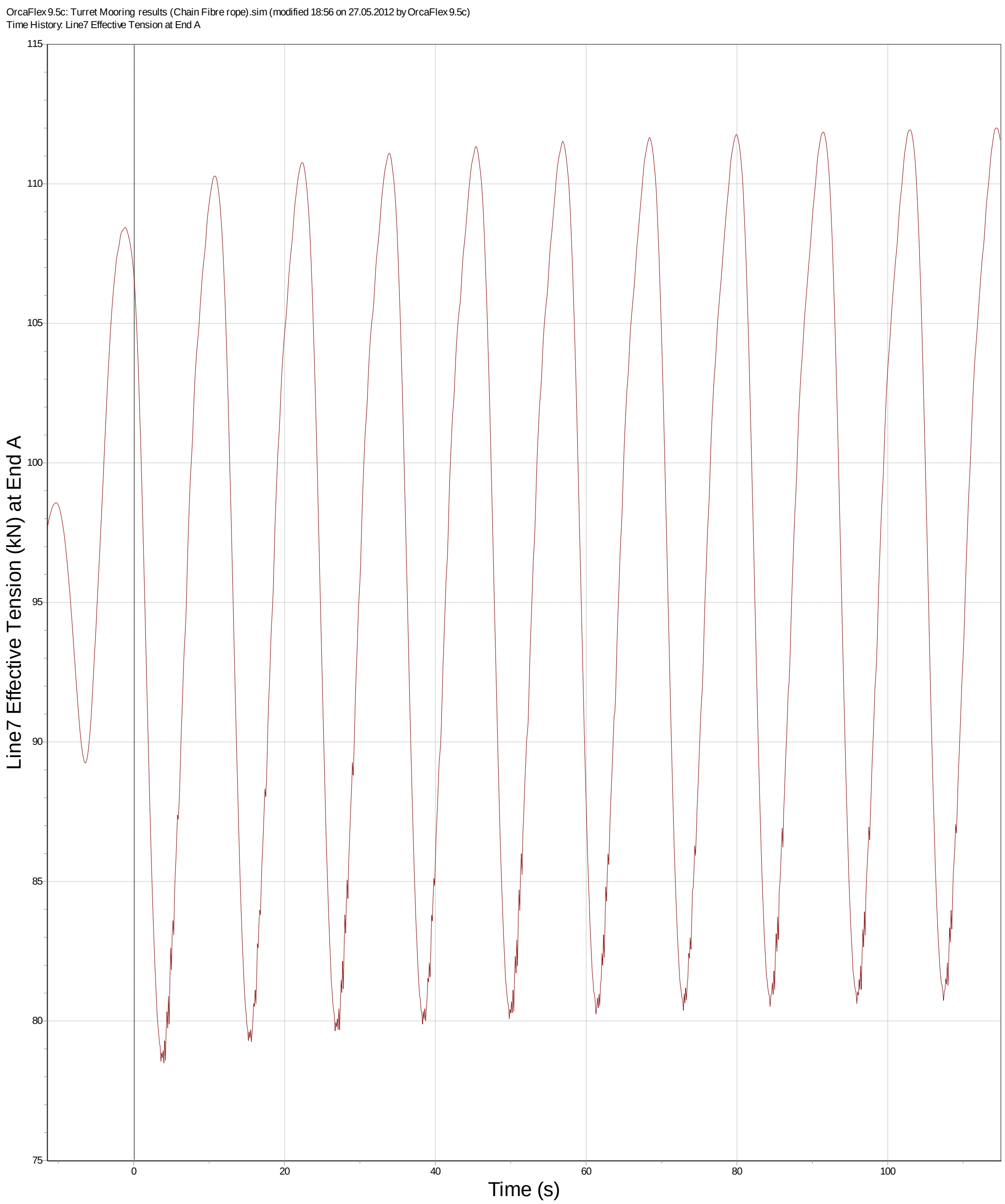


Fig 6.19 **Time history results for Tension in Mooring line 7 (Case 1)**

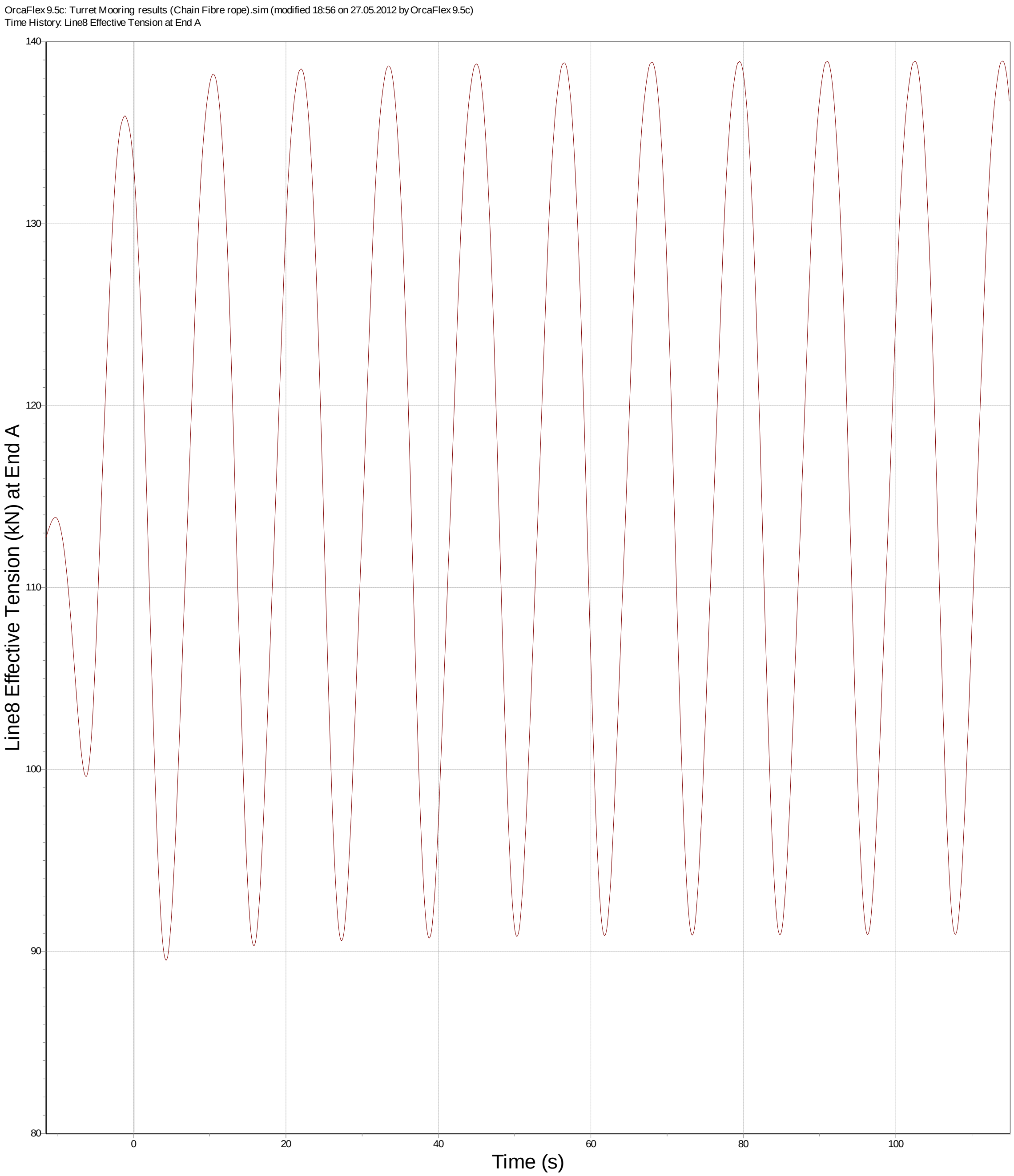


Fig 6.20 **Time history results for Tension in Mooring line 8 (Case 1)**

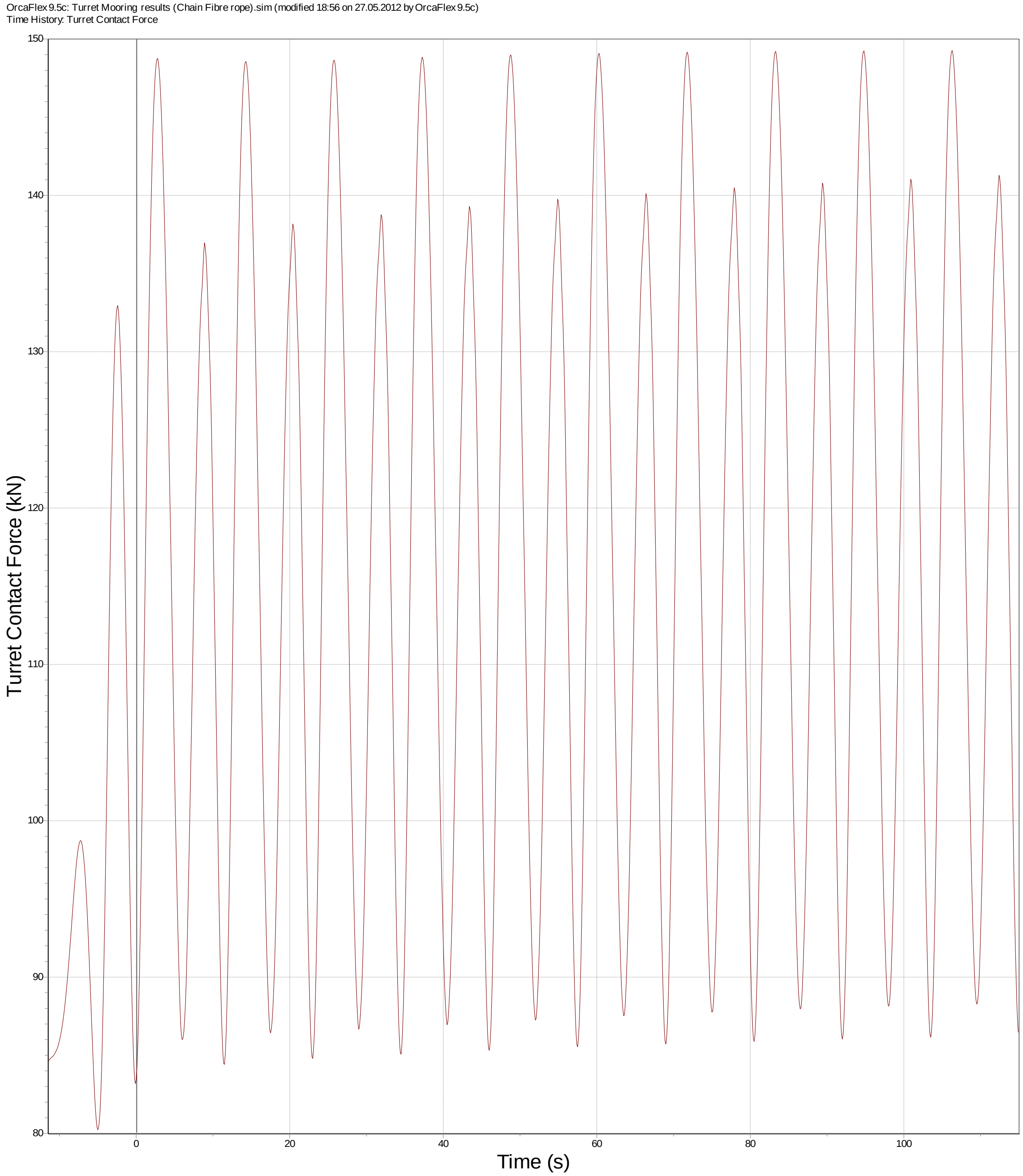


Fig 6.21 **Time history results for Turret contact force (Case 1)**

6.3 Case 2

Similarly, as in case 1, in case 2, an offshore vessel (103m long) is moored with eight symmetric mooring lines spaced 45° apart. The mooring lines comprise chain and wire rope. The mooring geometry is a catenary mooring system. The simulation uses regular waves acting on the vessel for the period of 115 seconds. The mooring system employs a turret, located at the vessel's moonpool. Since all mooring lines are connected to the turret, the vessel is free to rotate about the turret-wellhead axis and head into oncoming seas, regardless of direction. Thrusters are also provided at the bow and stern to assist in maintaining a desired heading. The chain table connecting the mooring line to the turret is above the waterline.

The wire rope/chain arrangement is an alternative to case 1 discussed earlier. In the wire rope/chain combination system, the wire rope segments are connected to the vessel via the turret while the chain segments are connected to the anchor. A length of chain is used in the dip zone where the mooring line is in dynamic contact with the seafloor. This minimizes the amount of chain used, when compared to case 1. A screen shot of the chain/wire rope mooring system taken from the OrcaFlex simulation file after the dynamic analysis is shown in Fig 6.23 below.

In the model, the turret is represented by an elastic solid body, cylindrical in shape which is placed within the hull, in a moonpool. The chain is drawn as yellow in the model and the wire ropes are drawn blue. The water depth is 500m and the wave theory used in the analysis is Dean Stream. The mechanical properties of the chain and fiber rope used in this analysis are shown in tables 6.7 and 6.8 respectively.

The 900m long mooring line is composed of wire rope (600m) and chain (250m) respectively. The prevailing environmental condition for Case2 is presented in Table 6.7 below.

Table 6.7 Environmental data (Case 2)

WAVE DATA	
Wave type	Dean Stream
Wave height (m)	16.0
Wave period (s)	11.5
Wave direction (deg)	180.0
Wave length (m)	228.0449
Wave number (rad/m)	0.0276
Ursell number	0.0039
Breaking wave height (m)	28.9094

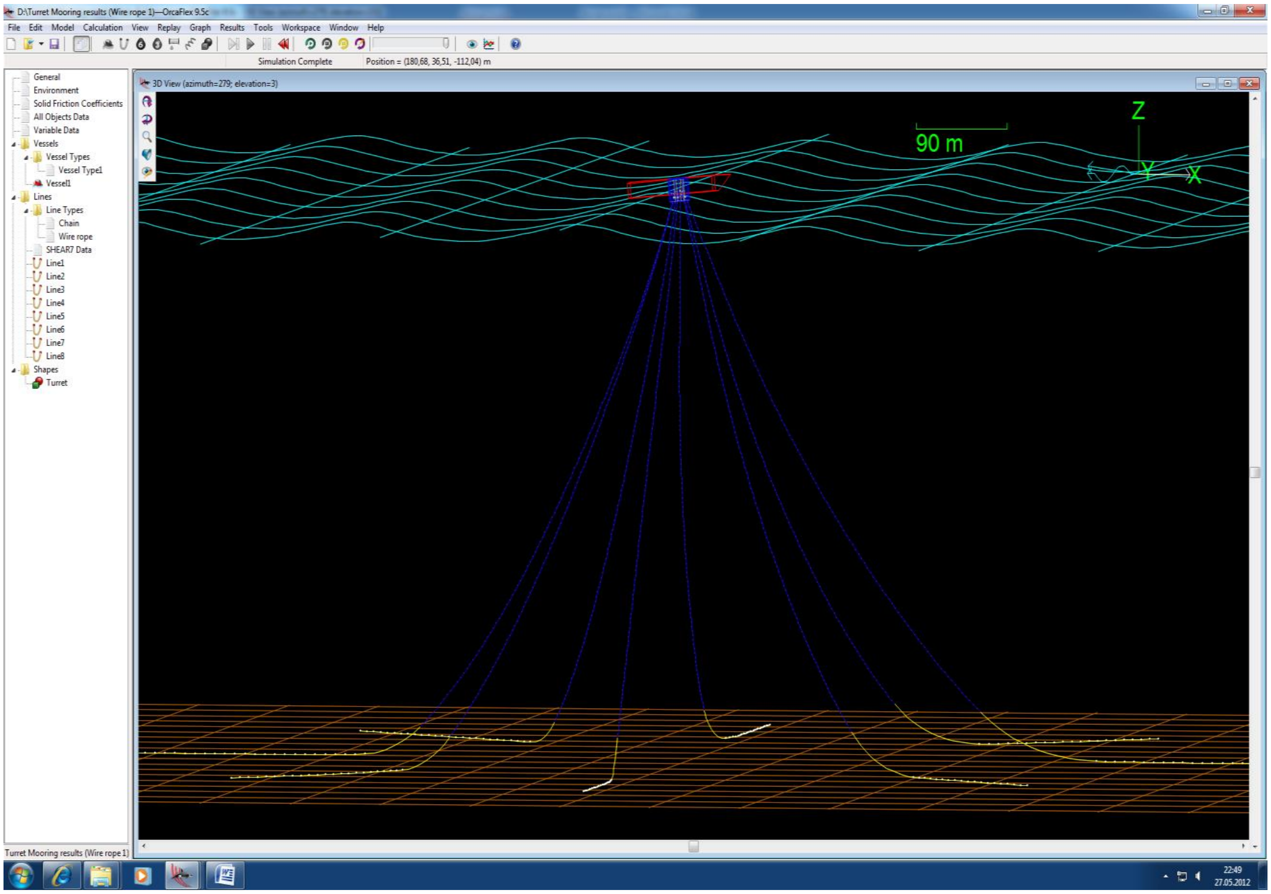


Fig 6.23 **Wire rope/chain mooring system (Case 2)**

Table 6.8 Properties of Chain (Case 2)

CHAIN PROPERTIES	
Outer Diameter (m)	0.094
Inner Diameter (m)	0
Bulk Modulus	Infinity
Weight in air (te/m)	0.055
Poisson ratio	0.5
Weight in water(te/m)	0,048
Displacement (te/m)	0,0072
Diameter/Weight Ratio	1,987m/(te/m)
Bending stiffness KN.m^2	-
Axial stiffness KN.m^2	252500
Minimum Breaking Load (KN)	2740
Torsional stiffness KN.m^2	80

Table 6.9 Properties of wire rope (Case 2)

WIRE ROPE PROPERTIES	
Outer Diameter (m)	0.041
Inner Diameter (m)	0
Bulk Modulus	Infinity
Weight in air (te/m)	0.009
Poisson ratio	0.5
Weight in water(te/m)	0.0087
Displacement (te/m)	0.0013
Diameter/Weight Ratio	4.605
Bending stiffness $KN.m^2$	-
Axial stiffness $KN.m^2$	91750
Minimum Breaking Load (KN)	1583.396
Torsional stiffness $KN.m^2$	80

6.3.1 Results (case 2)

Similarly, as in case 1 in case 2, the range graph shows plots of the effective tension in each segment of the mooring lines against the arc length of the mooring lines. From the range graph, we can deduce what part/segment of each mooring line is subjected to the maximum tension. Also from the range graph result, we can also see which mooring line is undergoing the maximum effective tension. The maximum effective tension in the mooring lines for case 2 is presented in Table 6.10 below. The range graph values for case 2 are given in appendix 2-B.

Table 6.10 Maximum effective tension at arc length 0m (Case 2)

Mooring line	Direction with wave	Maximum Effective tension(kN)	Arc length
Line 1	In line with wave 0^0	203.99	0
Line 2	45^0	109.57	0
Line 3	90^0	146.23	0
Line 4	135^0	86.69	0
Line 5	180^0	117.14	0
Line 6	225^0	177.93	0
Line 7	270^0	127.49	0
Line 8	315^0	199.51	0

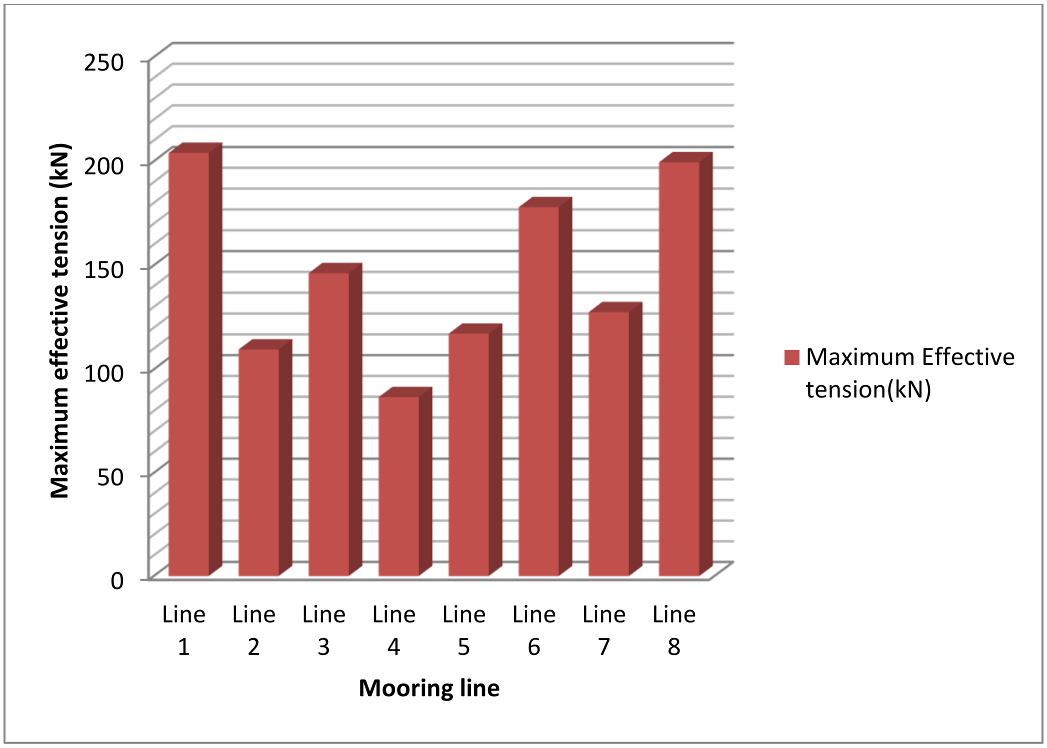


Fig 6.24 Maximum effective tension in mooring lines (Case 2)

6.3.2 Discussion of result (case 2)

From Table 6.10 and Fig 6.24 above, we can clearly deduce that the maximum effective tension is highest in mooring line 1, followed by mooring line 8 and lowest in mooring line 4. The maximum tension occurs at the turret end connection to the chains. This is as a result of the vessel motions induced by environmental forces. The greatest impact is felt at the turret end of each mooring line.

Table 6.11 shows the end forces in the mooring line. The distribution of the forces is quite similar to that of the effective tensions. The end forces were highest at mooring line 1, followed by mooring line 8 while the end forces were lowest at mooring line 4. We can also see that segment 2 is the maximum tension segment for case 2.

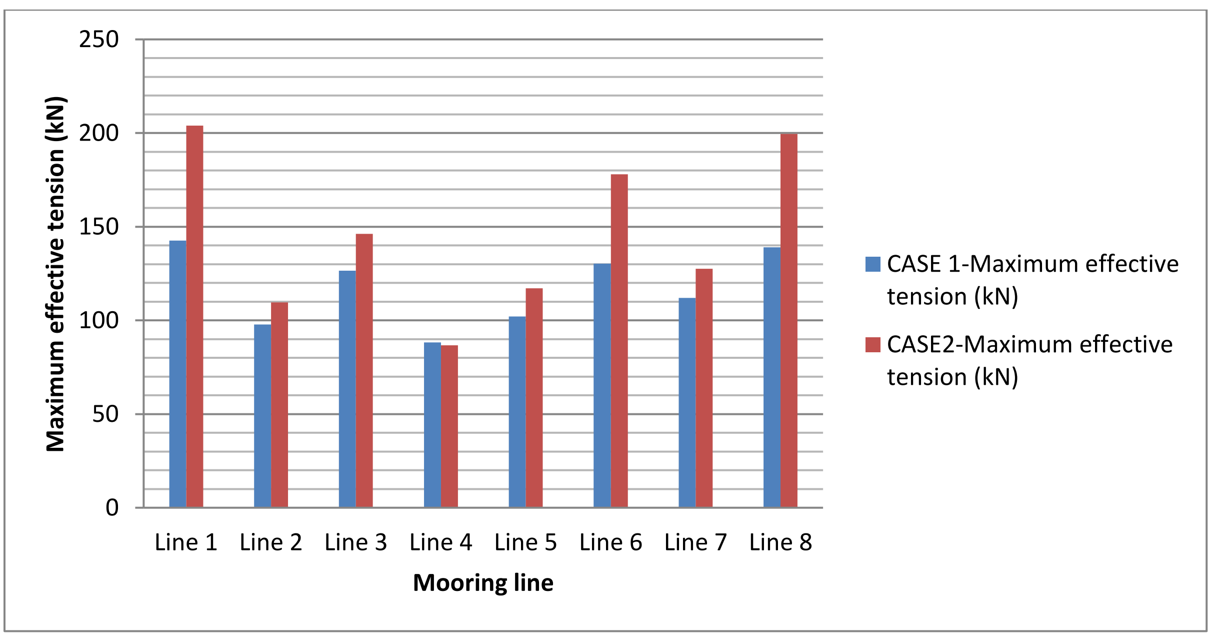
We can also see from the results that the maximum tension obtained in the mooring lines is much lower than the minimum breaking loads of the mooring line materials, as can be seen in Table 6.8 and Table 6.9. This implies that the design is adequate and the mooring system will sustain mooring loads under the prevailing environmental condition.

Table 6.11 Mooring line end forces (Case 2)

Connections							
	Vessel End			Anchor End		Maximum Tension Segment	
	Total	Vertical	Total Force	Total	Uplift	Segment	
Connection to	Force (kN)	Force (kN)	Declination (deg)	Force (kN)	Angle (deg)	Number	Tension (kN)
Line1 End A	165,6012	158,958	163,7162	124,0806	0,0	2	170,8758
Line2 End A	60,7323	60,1656	172,1669	44,041	0,0	2	64,9458
Line3 End A	106,9369	104,2119	167,0376	72,5187	0,0	2	113,1757
Line4 End A	52,2079	51,9479	174,2799	19,4032	0,0	2	56,2795
Line5 End A	65,9535	65,6044	174,1023	46,4216	0,0	2	71,284
Line6 End A	112,0061	110,0455	169,2638	78,7416	0,0	2	114,9597
Line7 End A	78,4554	77,911	173,2468	62,7108	0,0	2	82,315
Line8 End A	148,6468	145,2579	167,7422	108,4822	0,0	2	151,4975
Turret	29,0545	-0,6425	88,7328				

6.3.3 Comparison of results in Case 1 and Case 2

From Table 6.4 and Table 6.10, we can clearly see that the maximum effective tensions in the mooring lines in case 1 are much lower than those obtained in case 2. This is as a result of the different mooring configuration. The fiber rope used in case 1 as part of the mooring line is lighter and more flexible than wire rope. The fiber rope can also absorb more imposed dynamic motions through extension without inducing more dynamic tension when compared to wire rope. A column chart showing the comparison of maximum effective tension in case 1 and case 2 is shown in Fig 6.25 below.



6.25 Comparison of Case1 and Case 2

The range graph results for each mooring line in case 2 are shown in Fig 6.25 to Fig 6.32. The range graph plots enables us to see the minimum, maximum, mean effective tension across the arc length of the mooring lines for the whole simulation. In the range graph plot, the maximum effective tension is drawn green; the minimum effective tension is drawn blue while the mean effective tension is drawn brown. In case 2, Fig 6.26 shows that the tension dropped to zero in mooring line 1 at the connection area of the wire rope to the chain. This is also as a result of snap load. Peak tensions were obtained in mooring line 2, 3, 4 and 5 as can be seen in Figures 6.27, 6.28, 6.29 and 6.30 respectively.

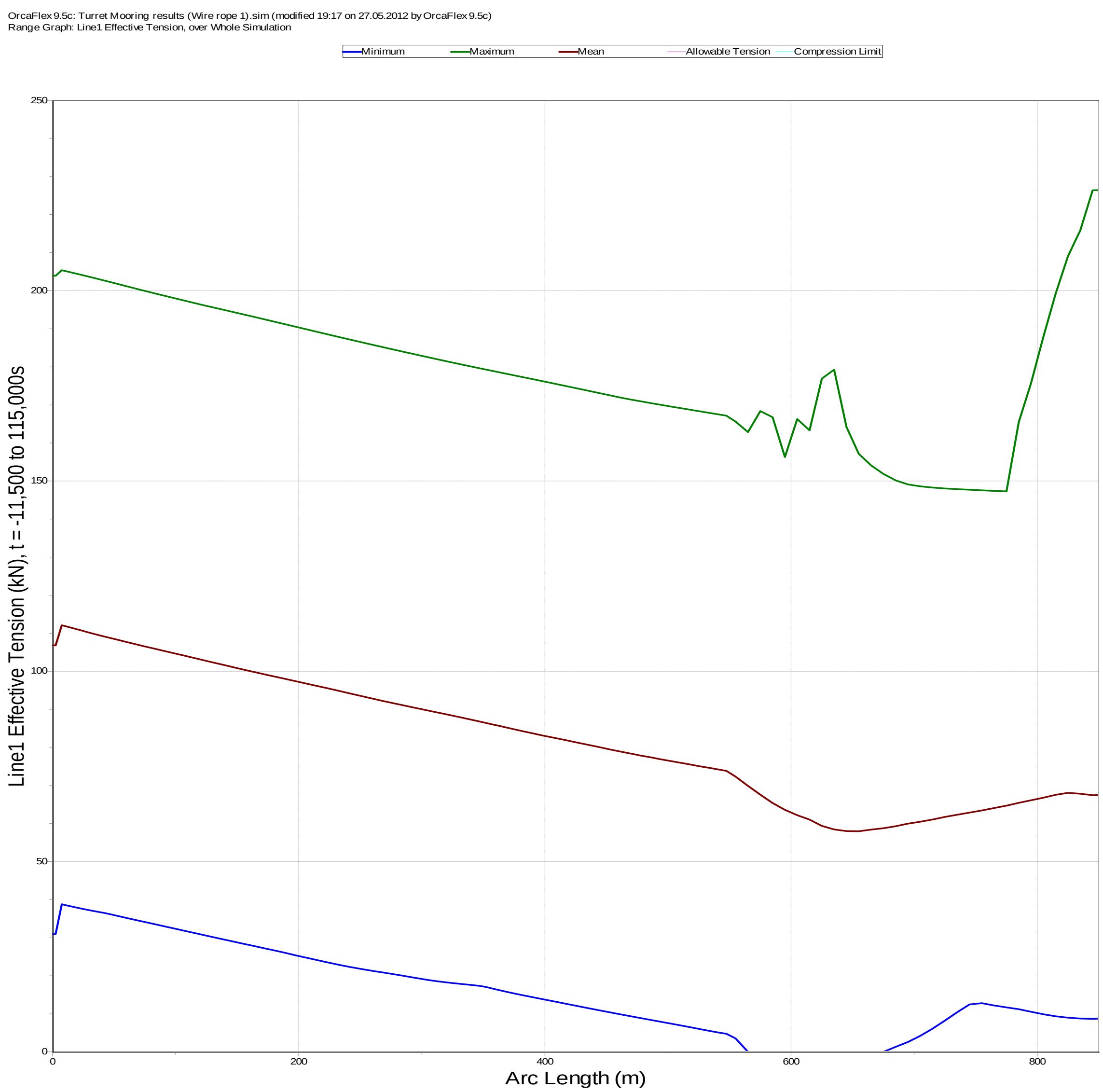


Fig 6.26 Range graph for mooring line 1 (case 2)

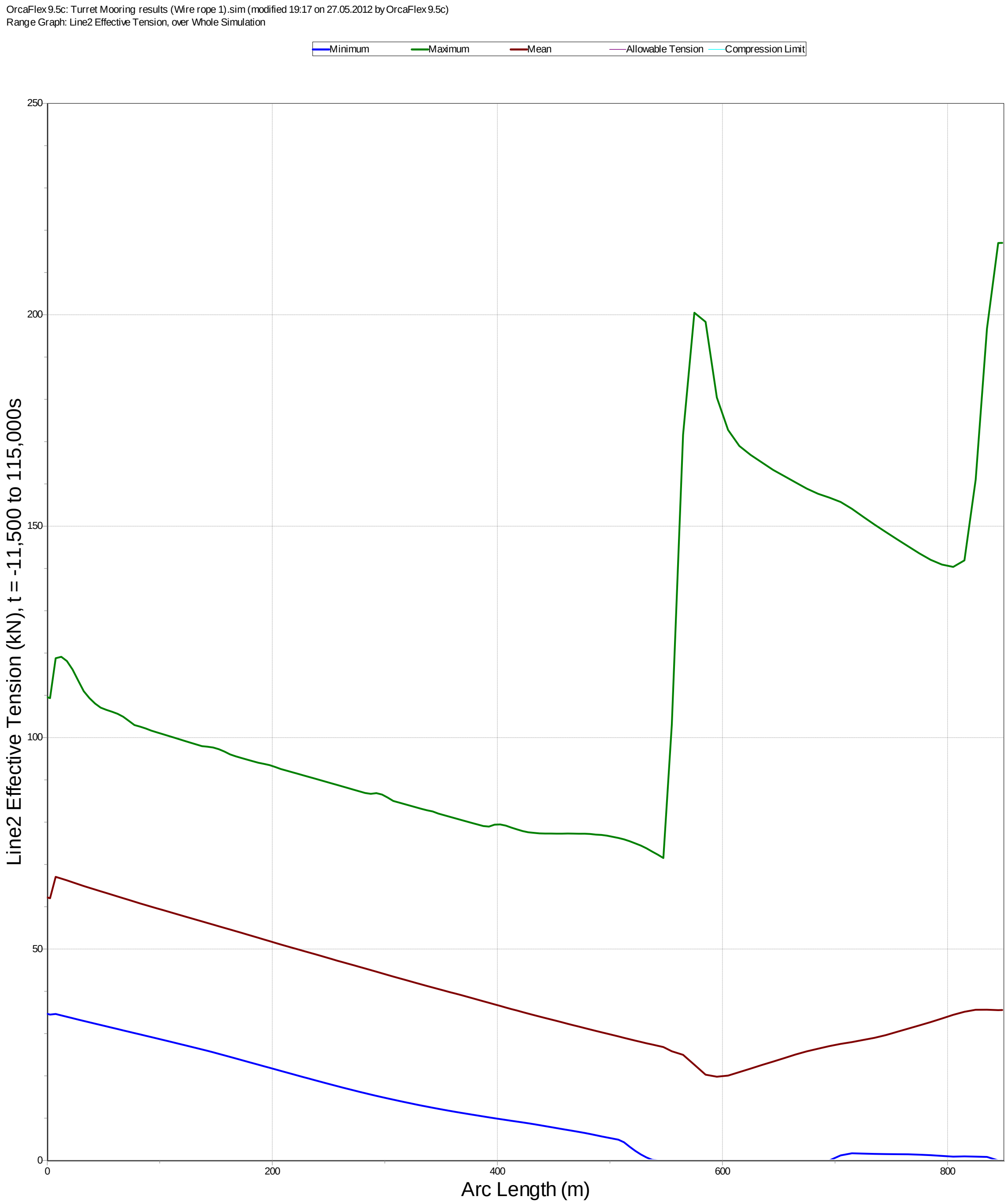


Fig 6.27 Range graph for mooring line 2 (case 2)

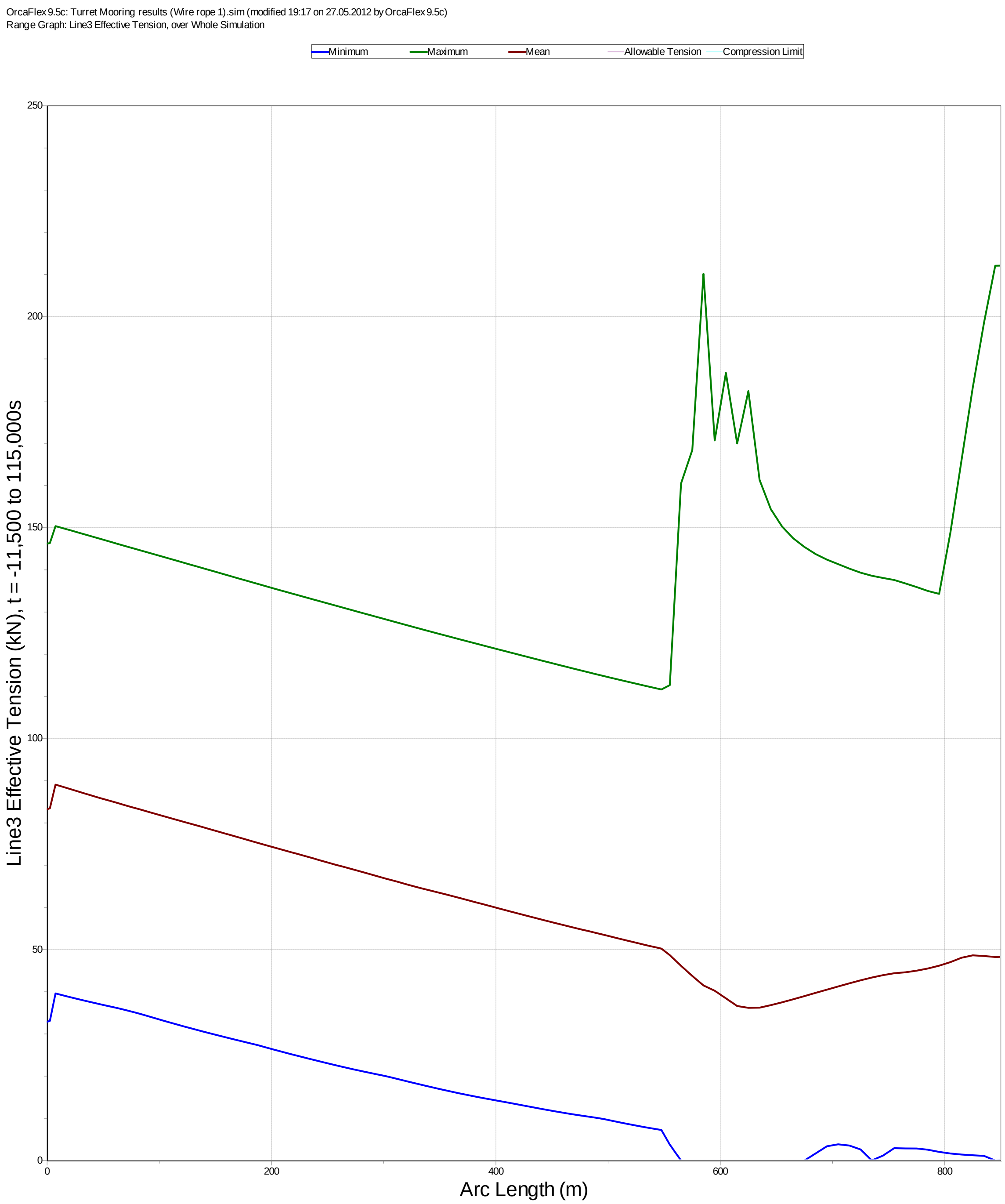


Fig 6.28 Range graph for mooring line 3 (case 2)

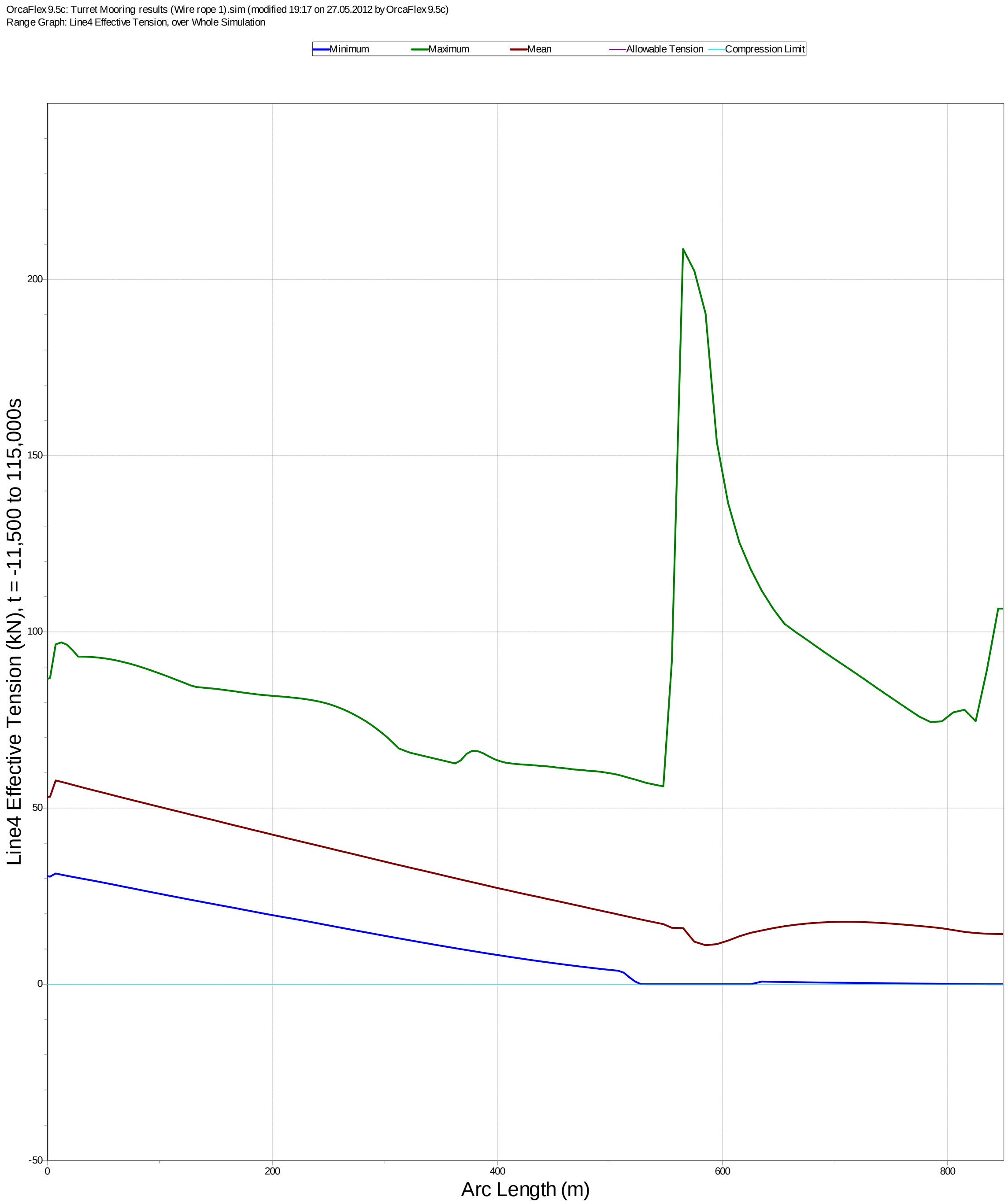


Fig 6.29 Range graph for mooring line 4 (case 2)

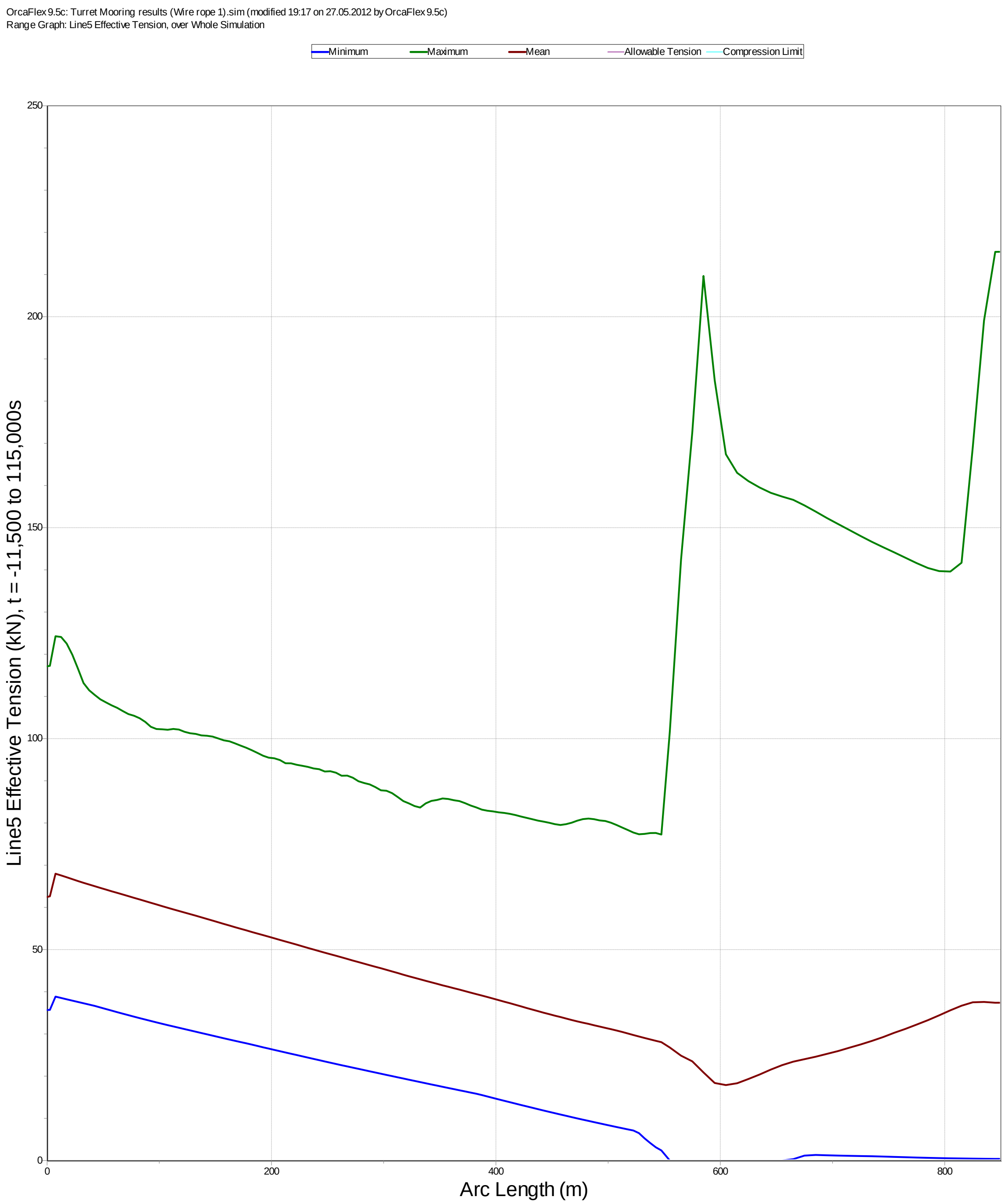


Fig 6.30 Range graph for mooring line 5 (case 2)

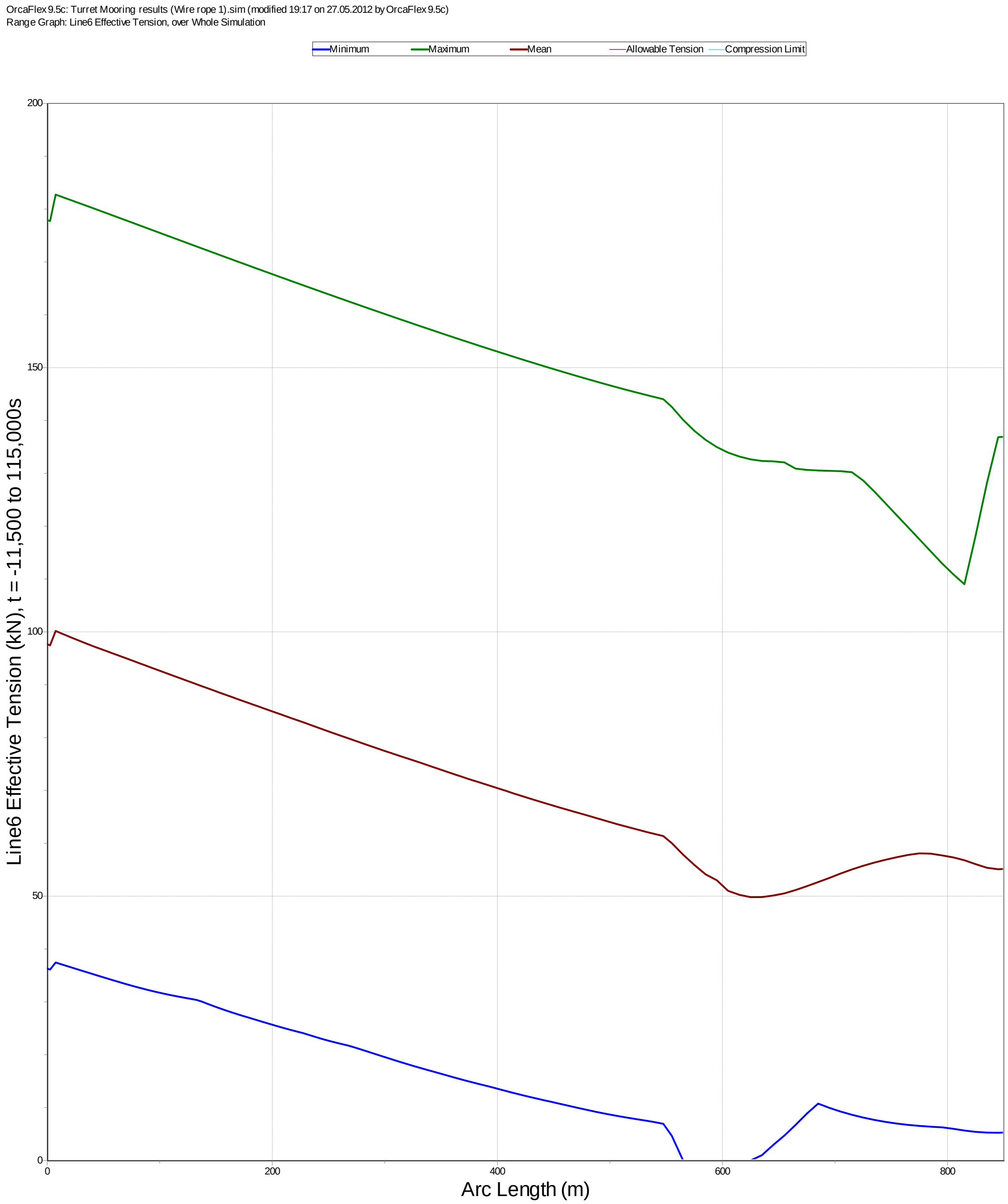


Fig 6.31 Range graph for mooring line 6 (case 2)

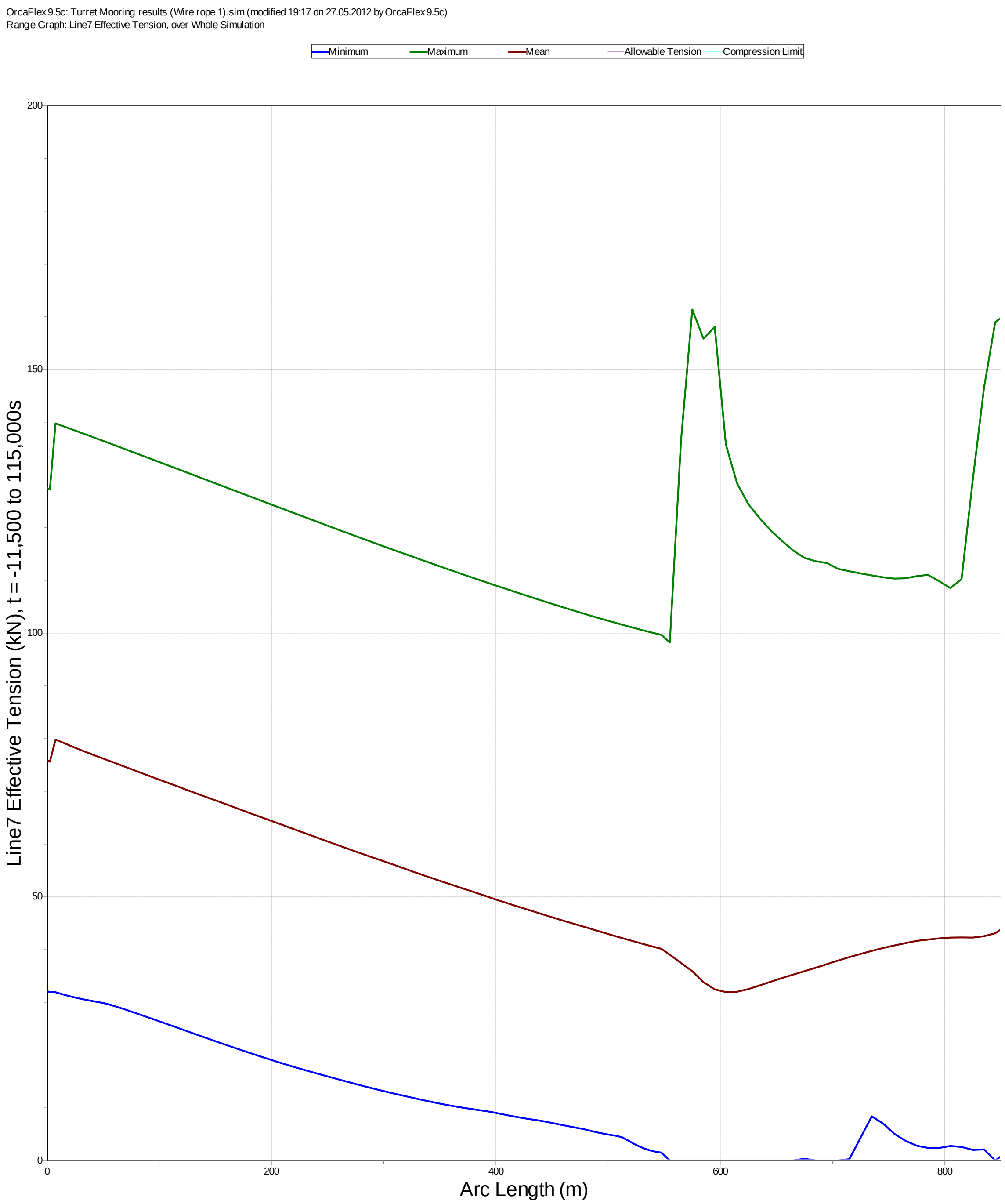


Fig 6.32 Range graph for mooring line 7 (case 2)

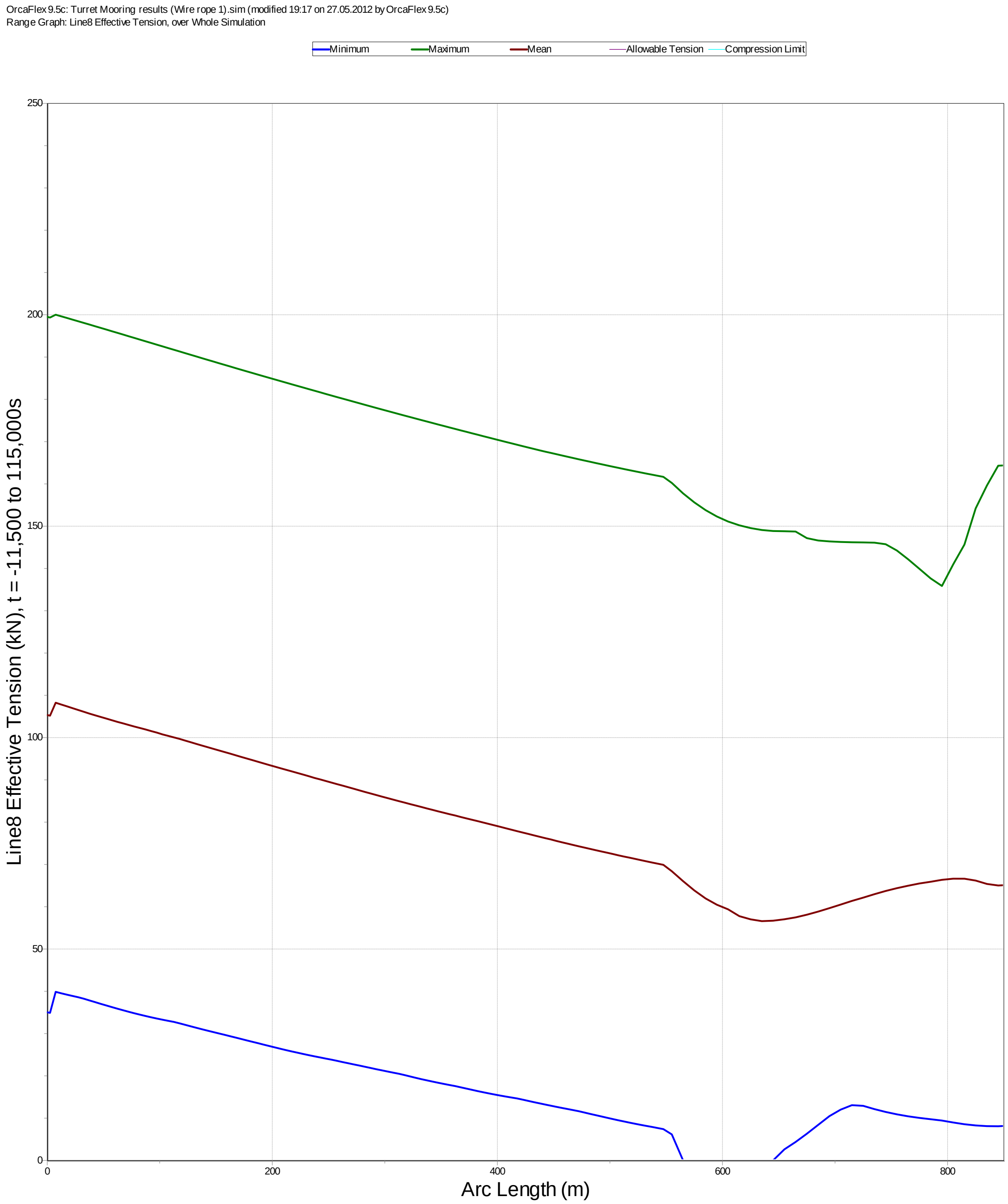


Fig 6.33 Range graph for mooring line 8 (case 2)

6.3.4 Time History results (Case 2)

The time history results show a plot of the sea elevation against the simulation time for the environment, and also shows the vessel elevation against the simulation time (t =11.5 -115 seconds). The time history results for the environment and vessel are shown in Fig 6.33 and Fig 6.34 respectively. The time history results values for case 2 are given in appendix 3-B.

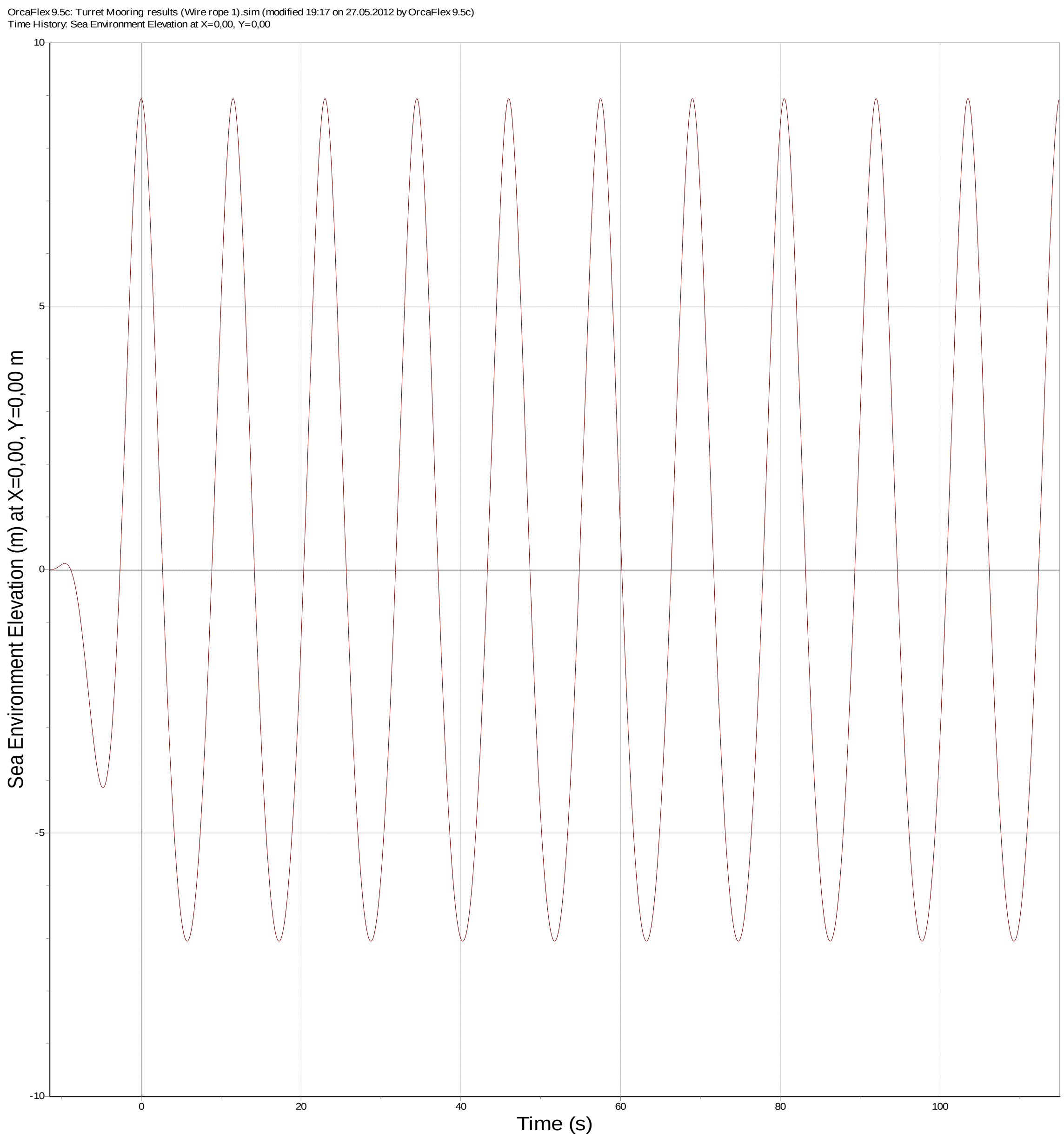


Fig 6.34 Time history result for sea environment (case 2)

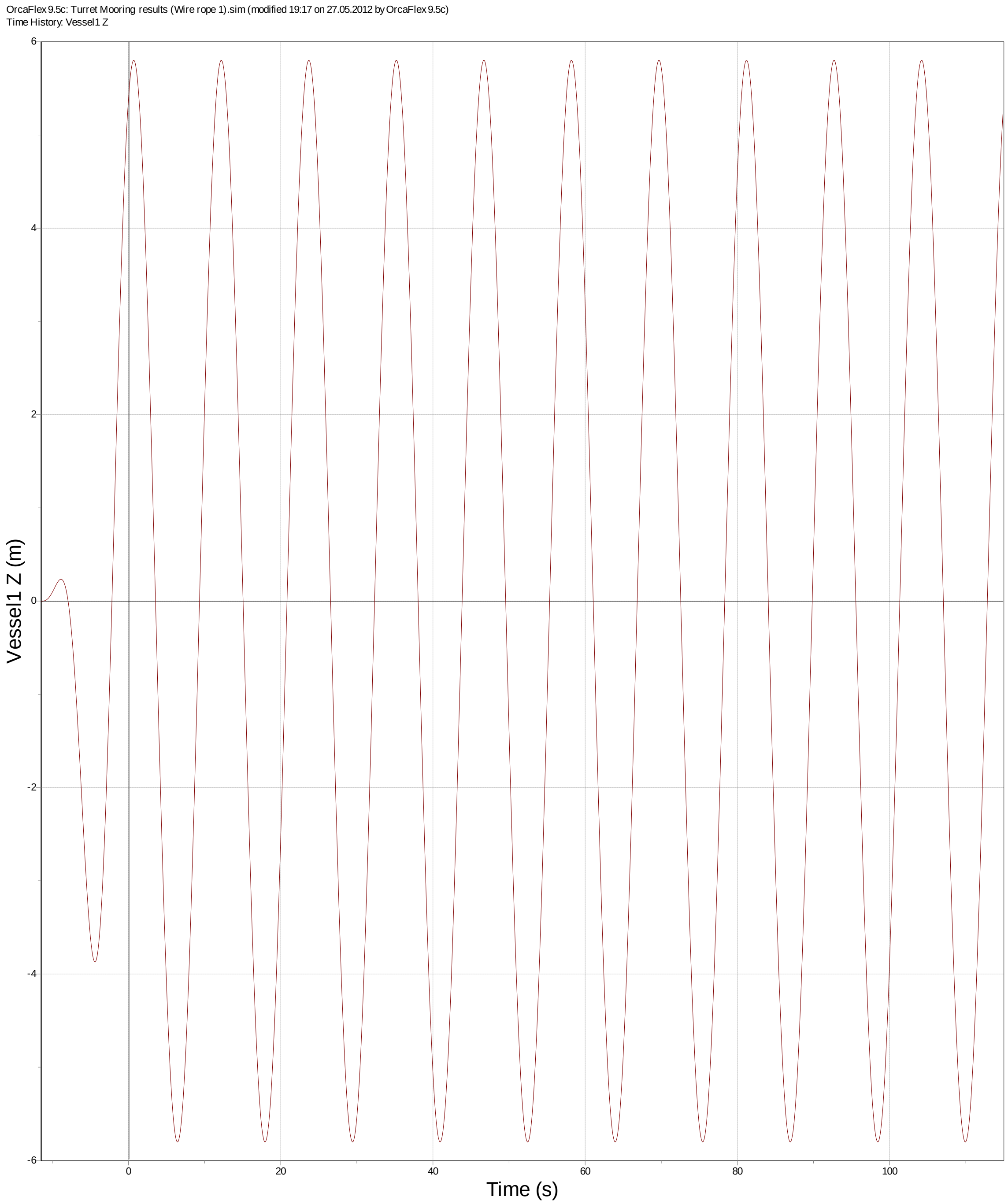


Fig 6.35 Time history result for vessel's vertical motion (case 2)

6.4 CASE 3

In this case, the offshore vessel is moored using eight symmetric mooring lines spaced 45° apart. The mooring lines comprise chain and wire rope. The mooring geometry is a catenary mooring system. The simulation uses regular waves acting on the vessel for the duration of 115 seconds. The vessel weighs 8800 tonnes and it is 103m long. The mooring system employs a turret, located at the vessel's moonpool. Since all mooring lines are connected to the turret, the vessel is free to rotate about the turret-wellhead axis and head into oncoming seas, regardless of direction. Thrusters are provided at the bow and stern to assist in maintaining a desired heading. The chain table connecting the mooring line to the turret is above the waterline.

The turret incorporates bearings that allow the vessel to rotate around the anchor legs. The mooring configuration in case 3 is such that a 50m chain is connected to the turret instead of wire rope as was the case in case 2.A 500m long Wire rope is connected to the end of the chain and a 200m chain connects the wire rope to the anchor on the sea floor. A screen shot of the chain/wire rope mooring system taken from the OrcaFlex simulation file after the dynamic analysis is shown in Fig 6.35.

Chain is used at the bottom of the mooring line to provide good abrasion resistance at the point of contact with the sea floor. The weight of the chain also contributes to the holding capacity of the anchor. The combination of chain and wire rope mooring lines with the right length selection offers the following advantages:

- Reduced pre- tension requirements with higher restoring force
- improved anchor holding capacity
- Good resistance to bottom abrasion.

These advantages make the combination of chain and wire rope mooring system suitable for deep water mooring.

In the model, the turret is represented by an elastic solid body, cylindrical in shape which is placed within the hull, in a moonpool. The chain is drawn as yellow in the model and the wire ropes are drawn blue. The water depth is 500m and the wave theory used in the analysis is Dean Stream. The prevailing environmental condition for case 3 analysis is shown in Table 6.12. The mechanical properties of the chain and wire rope used in this analysis are shown in Tables 6.13 and 6.14 respectively.

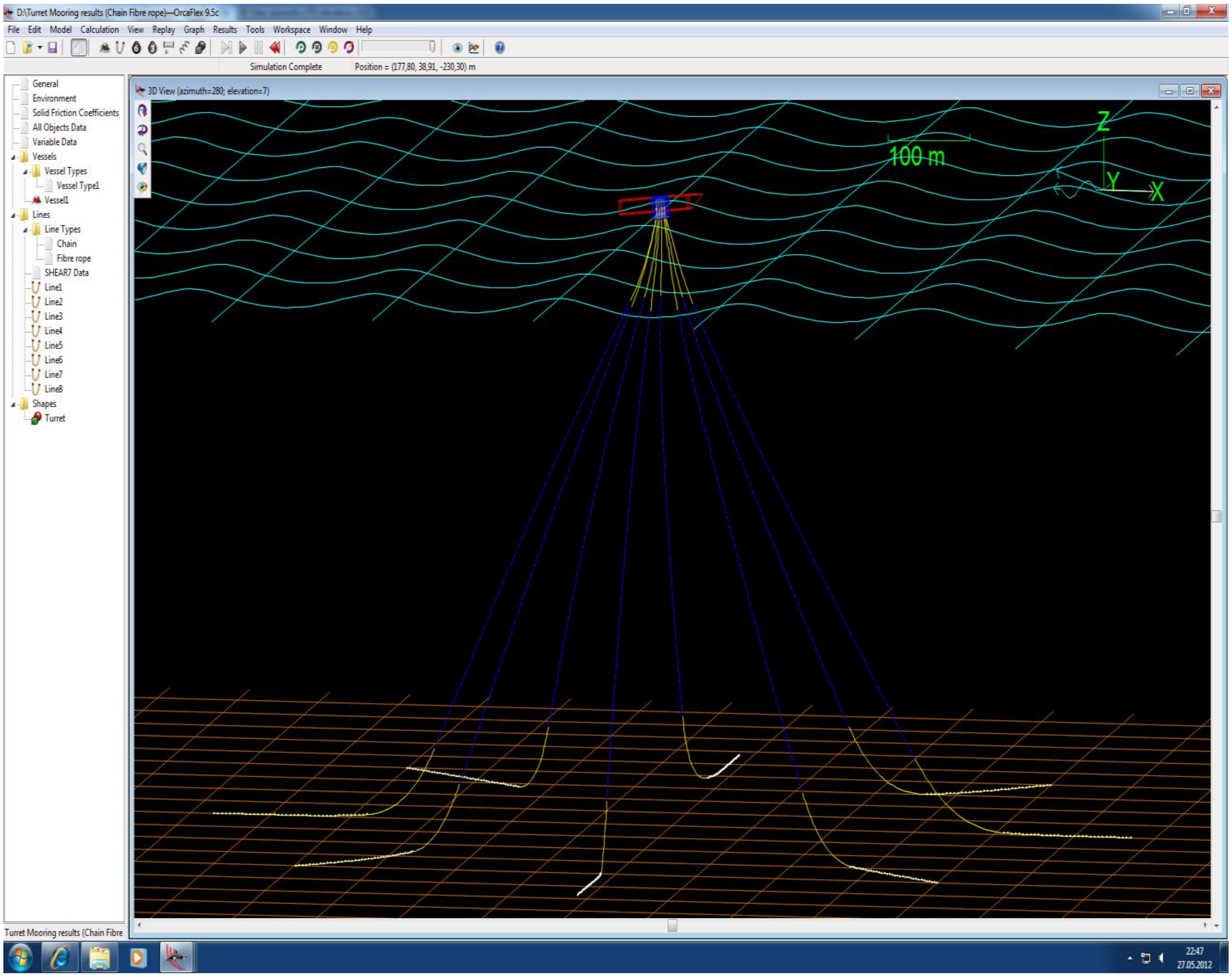


Fig 6.36 Chain/wire rope mooring (Case 3)

Table 6.12 Environmental data (Case 3)

WAVE DATA	
Wave type	Dean Stream
Wave height (m)	16.0
Wave period (s)	11.5
Wave direction (deg)	180.0
Wave length (m)	228.0449
Wave number (rad/m)	0.0276
Ursell number	0.0039
Breaking wave height (m)	28.9094

Table 6.13 Properties of Chain (Case 3)

CHAIN PROPERTIES	
Outer Diameter (m)	0.094
Inner Diameter (m)	0
Bulk Modulus	Infinity
Weight in air (te/m)	0.055
Poisson ratio	0.5
Weight in water(te/m)	0,048
Displacement (te/m)	0,0072
Diameter/Weight Ratio	1,987m/(te/m)
Bending stiffness $KN.m^2$	-
Axial stiffness $KN.m^2$	252500
Minimum Breaking Load (KN)	2740
Torsional stiffness $KN.m^2$	80

Table 6.14 Properties of wire rope (Case 3)

WIRE ROPE PROPERTIES	
Outer Diameter (m)	0.041
Inner Diameter (m)	0
Bulk Modulus	Infinity
Weight in air (te/m)	0.009
Poisson ratio	0.5
Weight in water(te/m)	0.0087
Displacement (te/m)	0.0013
Diameter/Weight Ratio	4.605
Bending stiffness $KN.m^2$	-
Axial stiffness $KN.m^2$	91750
Minimum Breaking Load (KN)	1583.396
Torsional stiffness $KN.m^2$	80

6.4.1 Results (case 3)

In case 3 the range graphs show plots of the effective tension in each segment of the mooring lines against the arc length of the mooring lines. From the range graph, we can deduce what part/segment of each mooring line is subjected to the maximum tension. Also from the range graph result, we can also see which mooring line is undergoing the maximum effective tension. The maximum effective tension in the mooring lines for case 3 is presented in Table 6.15 below. The range graph values for case 3 are presented in appendix 2-C.

Table 6.15 Maximum effective tension at arc length 0m (Case 3)

Mooring line	Direction with wave	Maximum Effective tension(kN)	Arc length
Line 1	In line with wave 0^0	421.87	0
Line 2	45^0	223.16	0
Line 3	90^0	346.50	0
Line 4	135^0	190.64	0
Line 5	180^0	311.3	0
Line 6	225^0	242.23	0
Line 7	270^0	197.22	0
Line 8	315^0	297.01	0

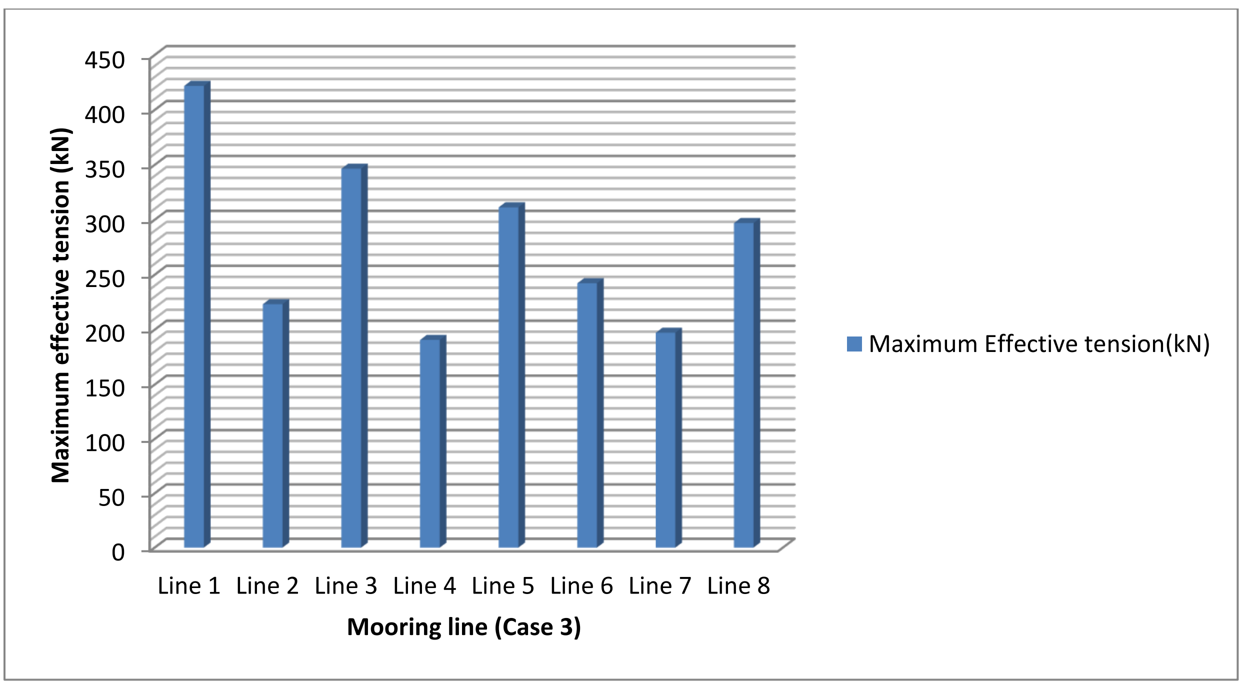


Fig 6.37 Maximum effective tension in mooring line (Case 3)

6.4.2 Discussion of results (case 3)

From Table 6.15 and Fig 6.37 we can see that higher tensions were obtained in the analysis for case 3. This is as a result of the extra chain added to the mooring line when compared to case 2. The highest value of maximum effective tension was observed in mooring line 1, followed by mooring line 3 while mooring line 4 had the lowest tension. Similarly, the maximum tension occurred at the turret end of the mooring lines. The increase in tension obtained in case 3 is due to the properties of chain used.

300m of chain was used in the mooring line configuration and wire rope is the remaining 550m.The 300m of chain used imposed an enormous weight burden on the vessel's load carrying capacity because of the chain's weight and also the attendant high tension requirements.

Furthermore, the end force results are presented in Table 6.16 below.

Table 6.16 End forces for Case 3

Connections							
	Vessel End			Anchor End		Maximum Tension Segment	
Connection to	Total Force (kN)	Vertical Force (kN)	Total Force Declination (deg)	Total Force (kN)	Uplift Angle (deg)	Segment Number	Tension (kN)
Line1 End A	404,4538	270,5234	131,9792	244,6683	0,0	1	409,3929
Line2 End A	96,5501	96,5495	179,8036	60,6317	0,0	2	104,8812
Line3 End A	305,4638	214,1826	134,5211	173,7547	0,0	1	318,3066
Line4 End A	108,4866	107,057	170,6882	75,8428	0,0	2	118,9191
Line5 End A	228,8315	158,5708	133,8648	107,873	0,0	1	239,6726
Line6 End A	171,7634	169,3642	170,4123	119,116	0,0	2	188,5437
Line7 End A	112,098	111,77	175,6156	82,1573	0,0	2	121,1297
Line8 End A	246,656	241,8253	168,6418	194,3821	0,0	2	268,9324
Turret	347,9321	21,3708	93,5215				

From Table 6.16, we can also see that the end forces were highest in mooring line 1 and lowest in mooring line 2. The total force acting on the turret is 347.93kN. The maximum tension occurred in the first segment of the mooring lines. The range graphs for each mooring line for case 3 are shown in Figures 6.38 to Fig 6.45.

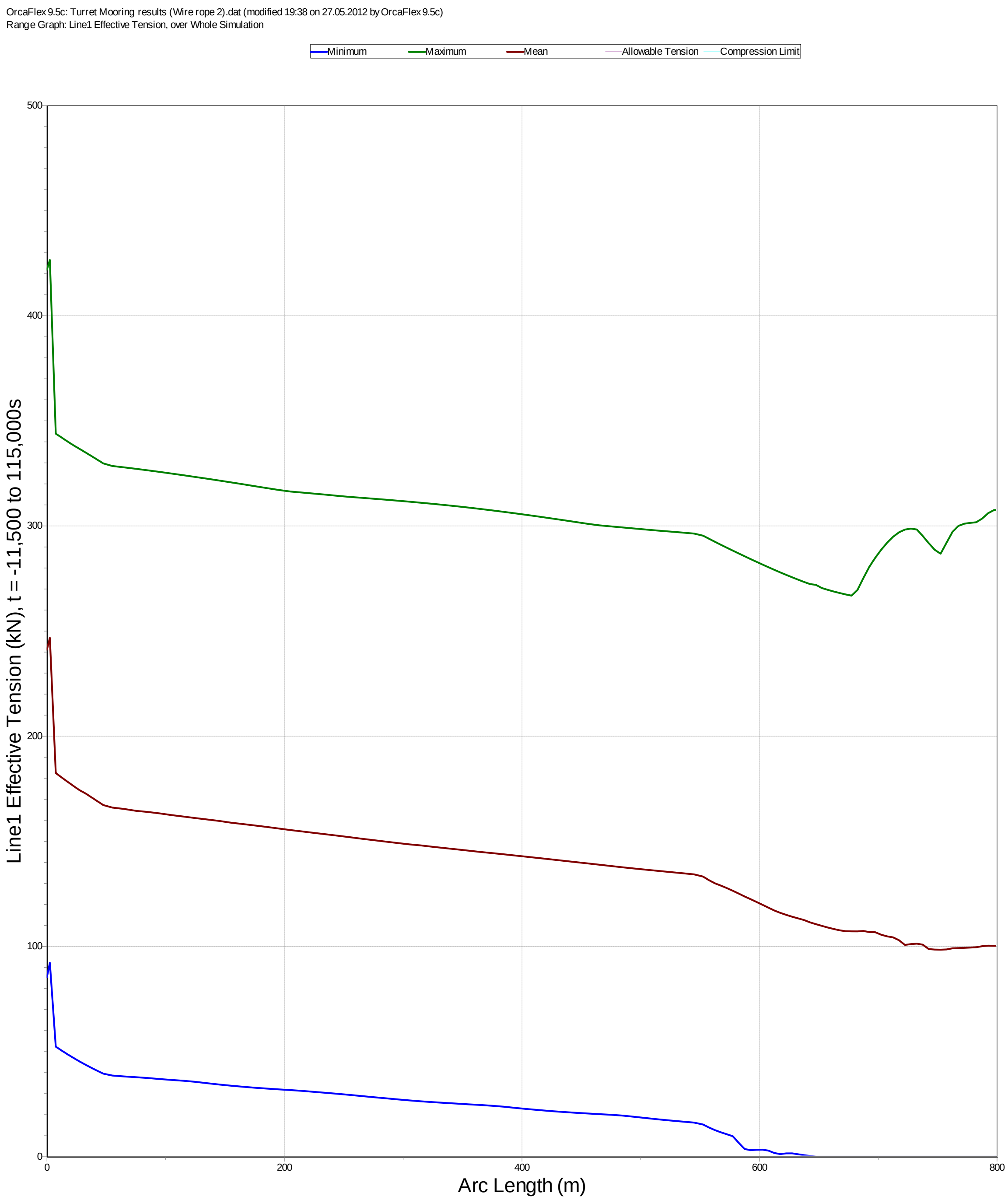


Fig 6.38 Range graph for tension in mooring line 1 (Case 3)

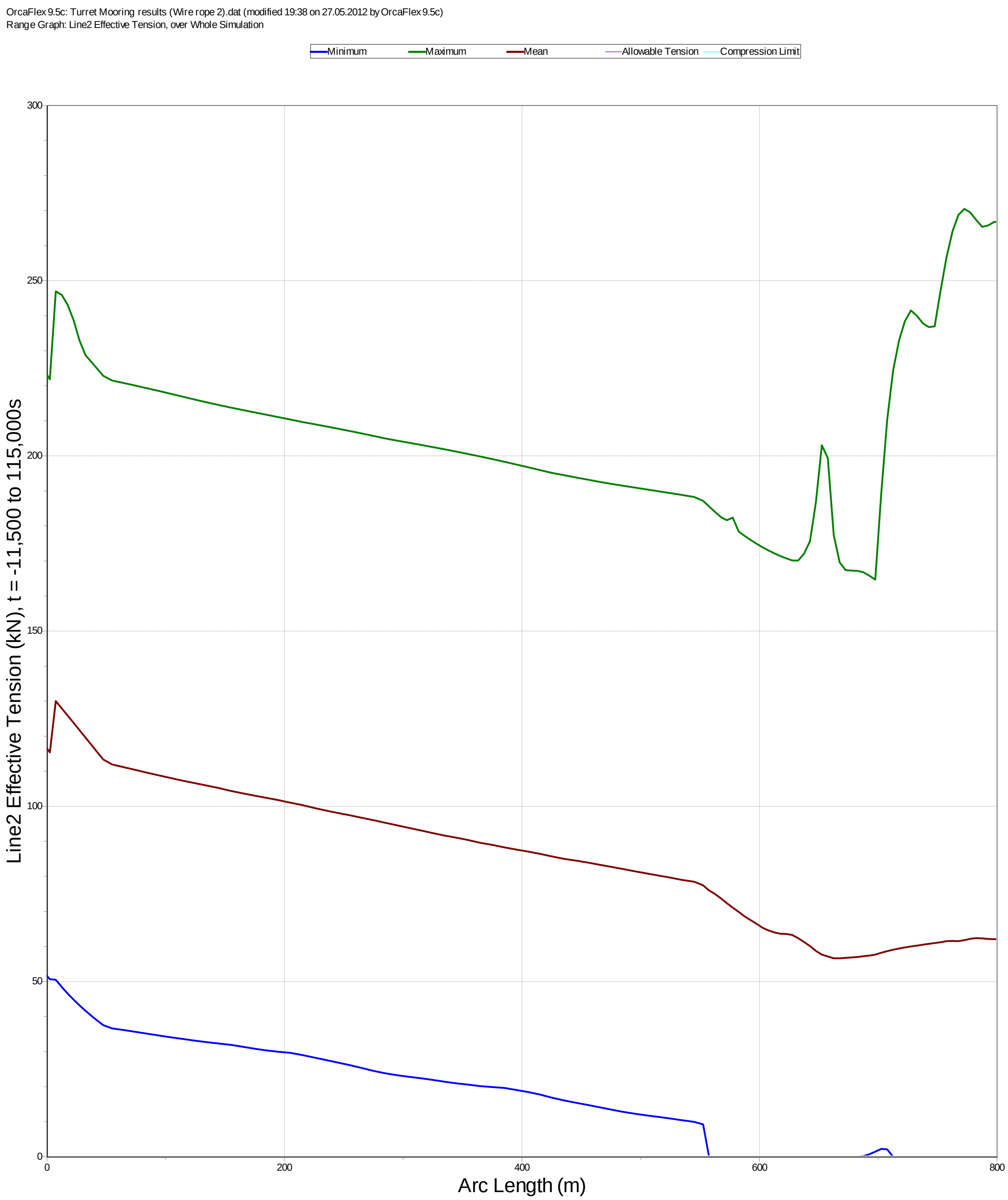


Fig 6.39 **Range graph for tension in mooring line 2 (Case 3)**

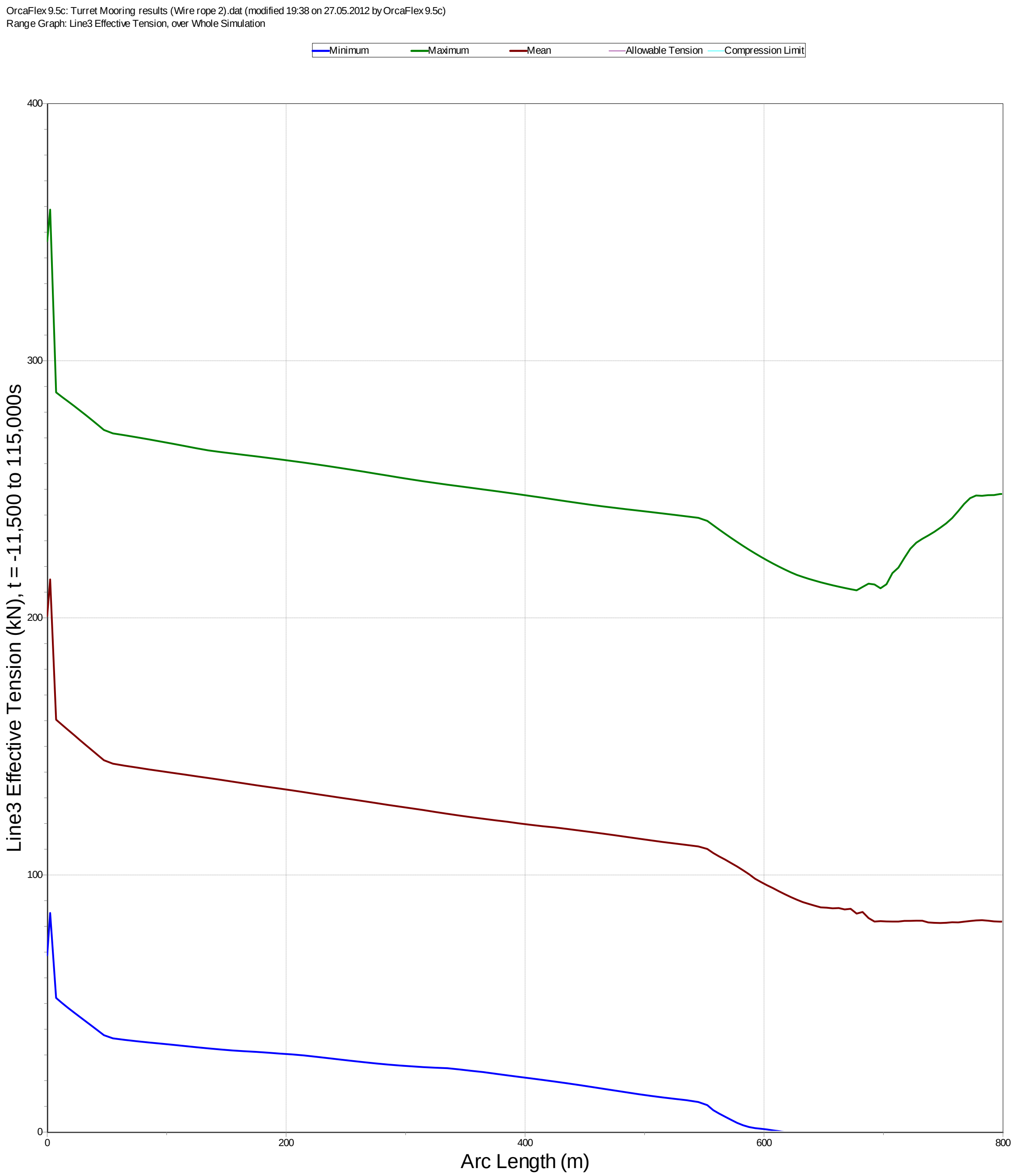


Fig 6.40 Range graph for tension in mooring line 3 (Case 3)

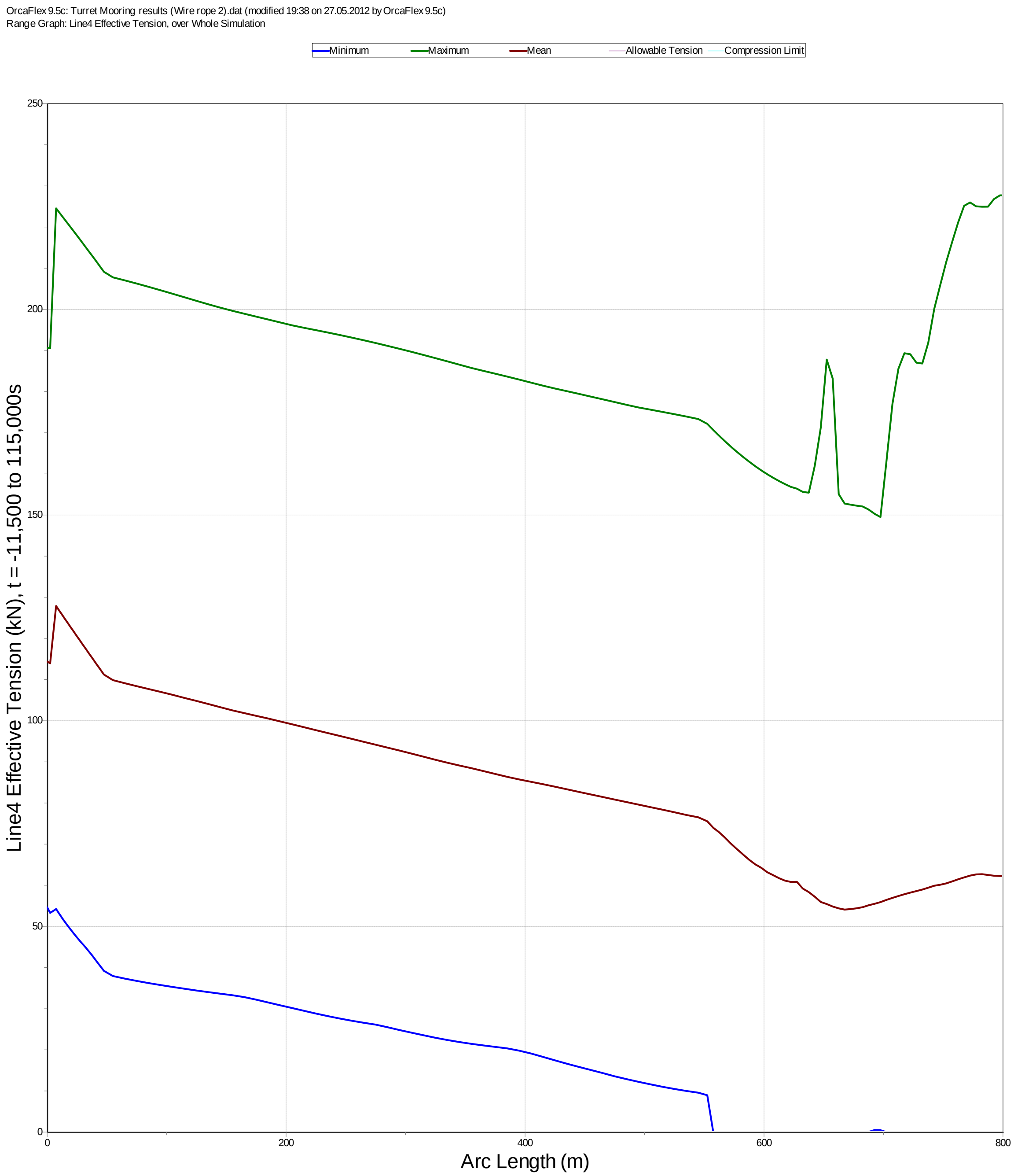


Fig 6.41 Range graph for tension in mooring line 4 (Case 3)

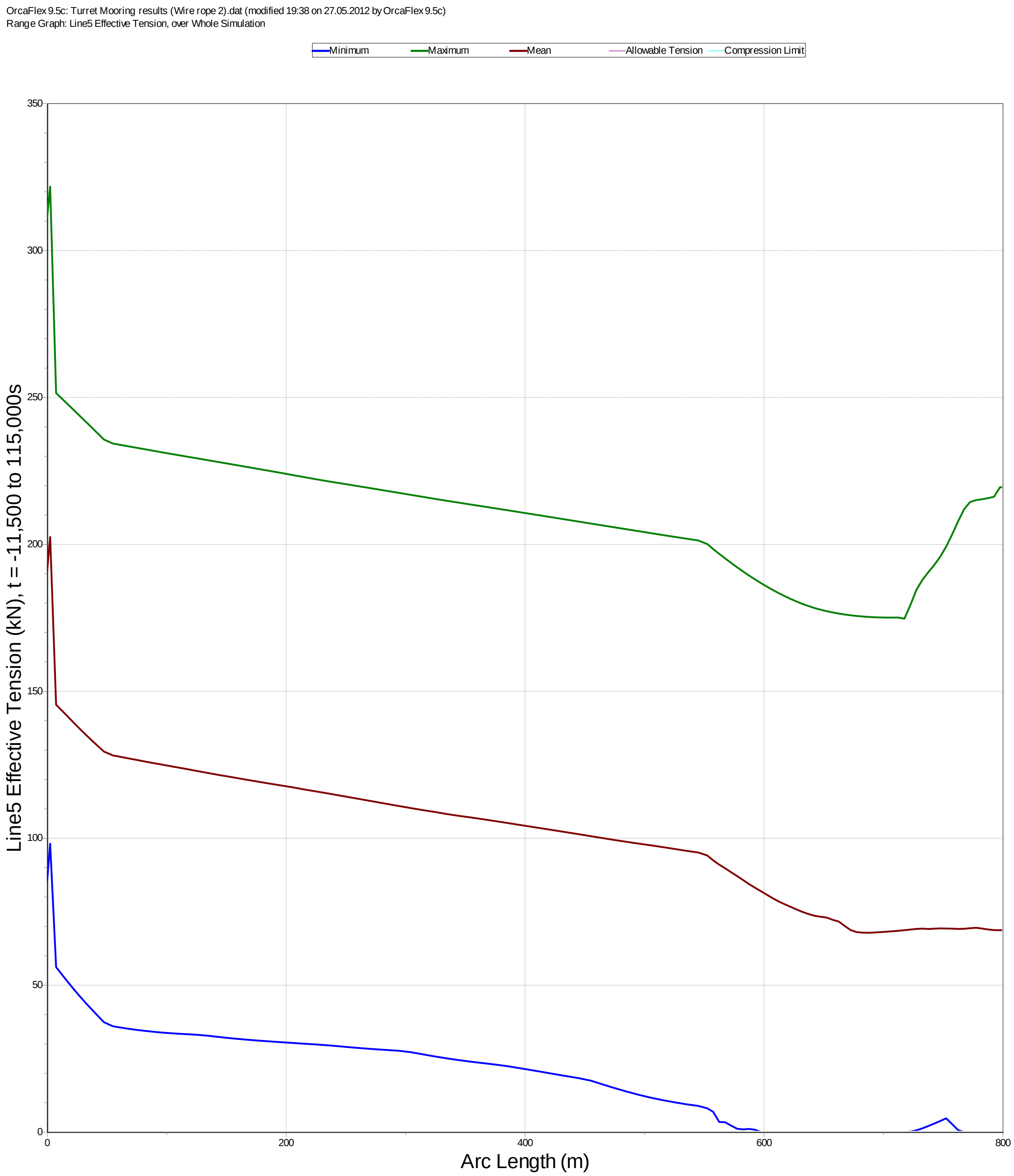


Fig 6.42 Range graph for tension in mooring line 5 (Case 3)

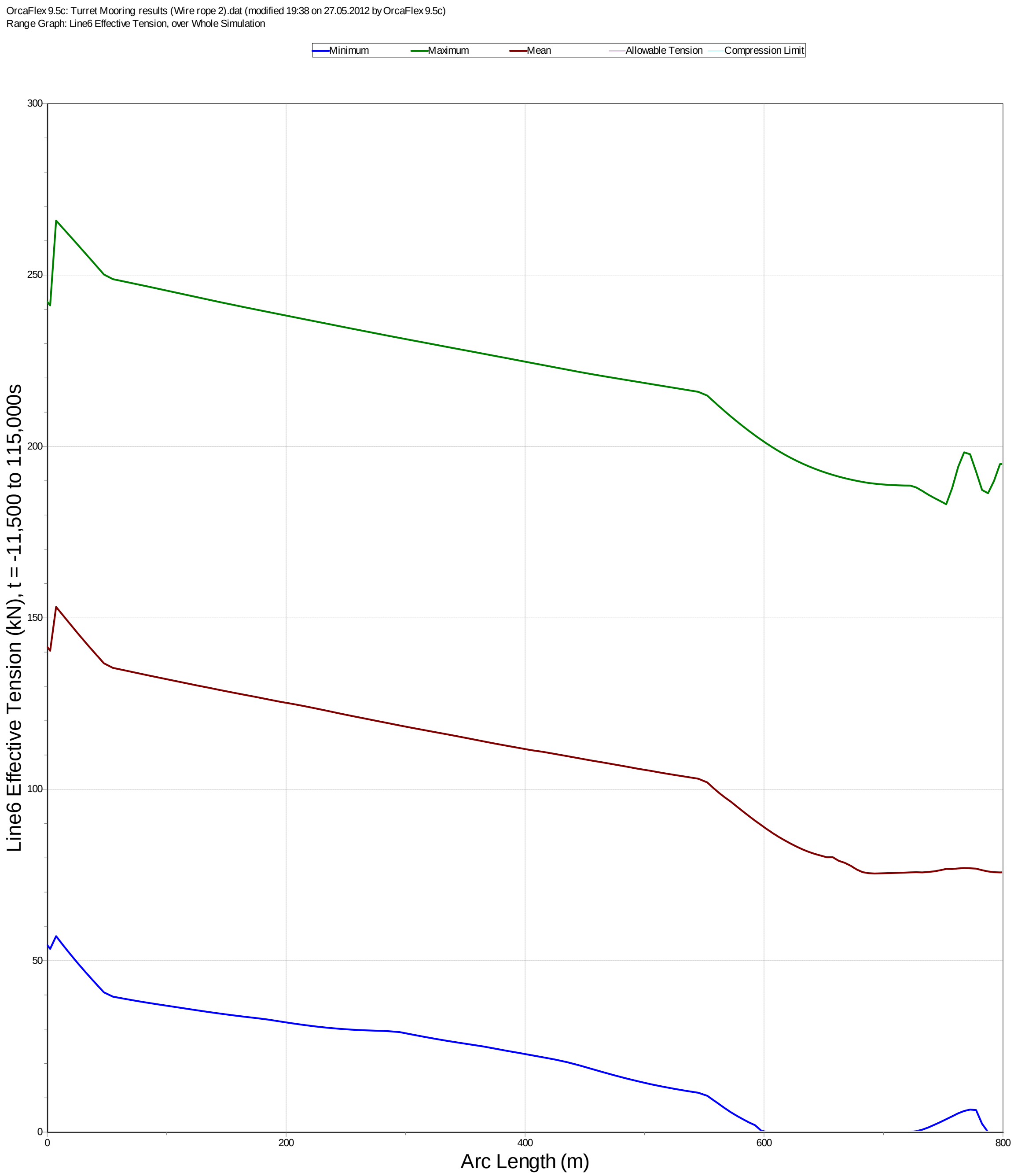


Fig 6.43 Range graph for tension in mooring line 6 (Case 3)

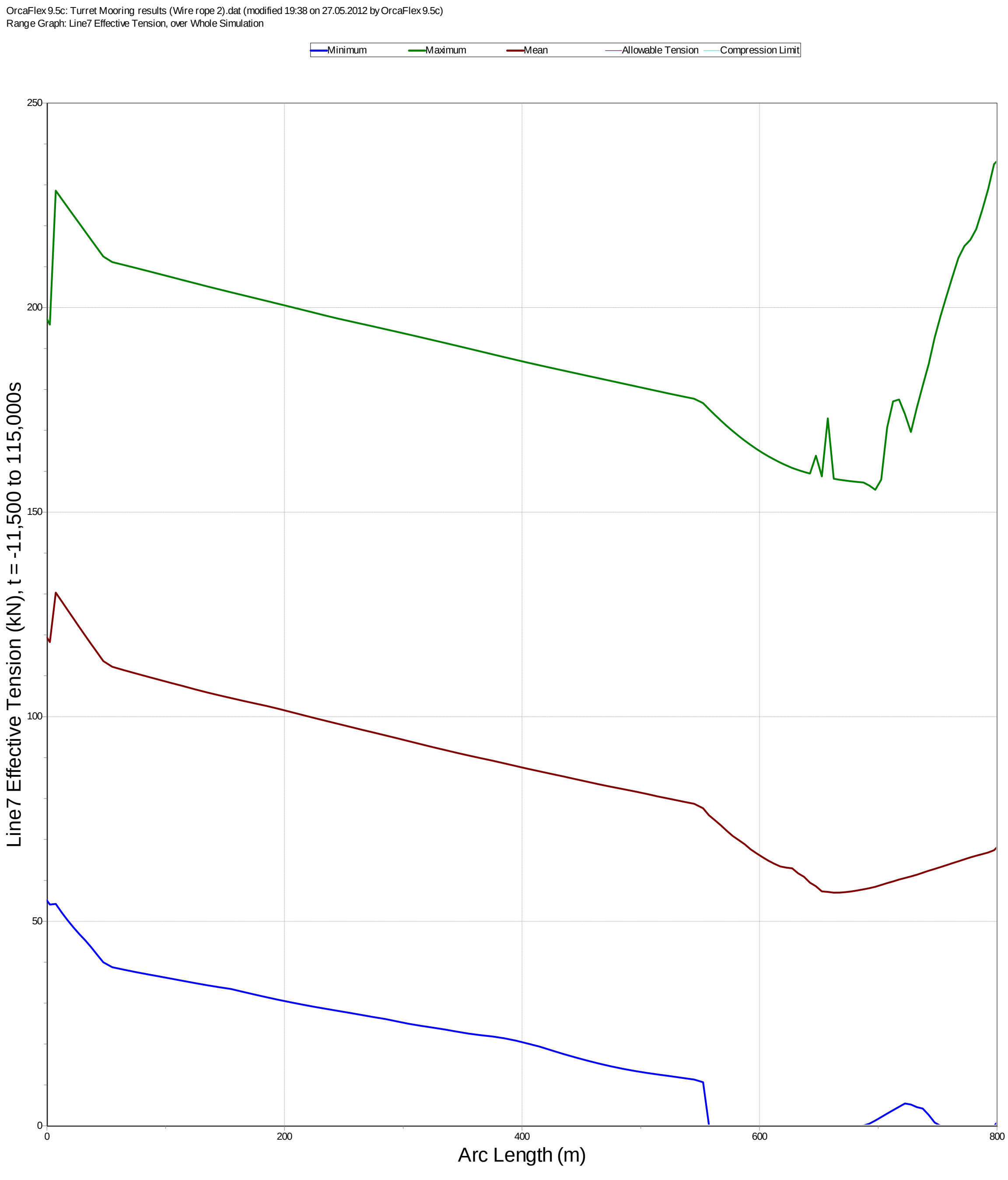


Fig 6.44 Range graph for tension in mooring line 7 (Case 3)

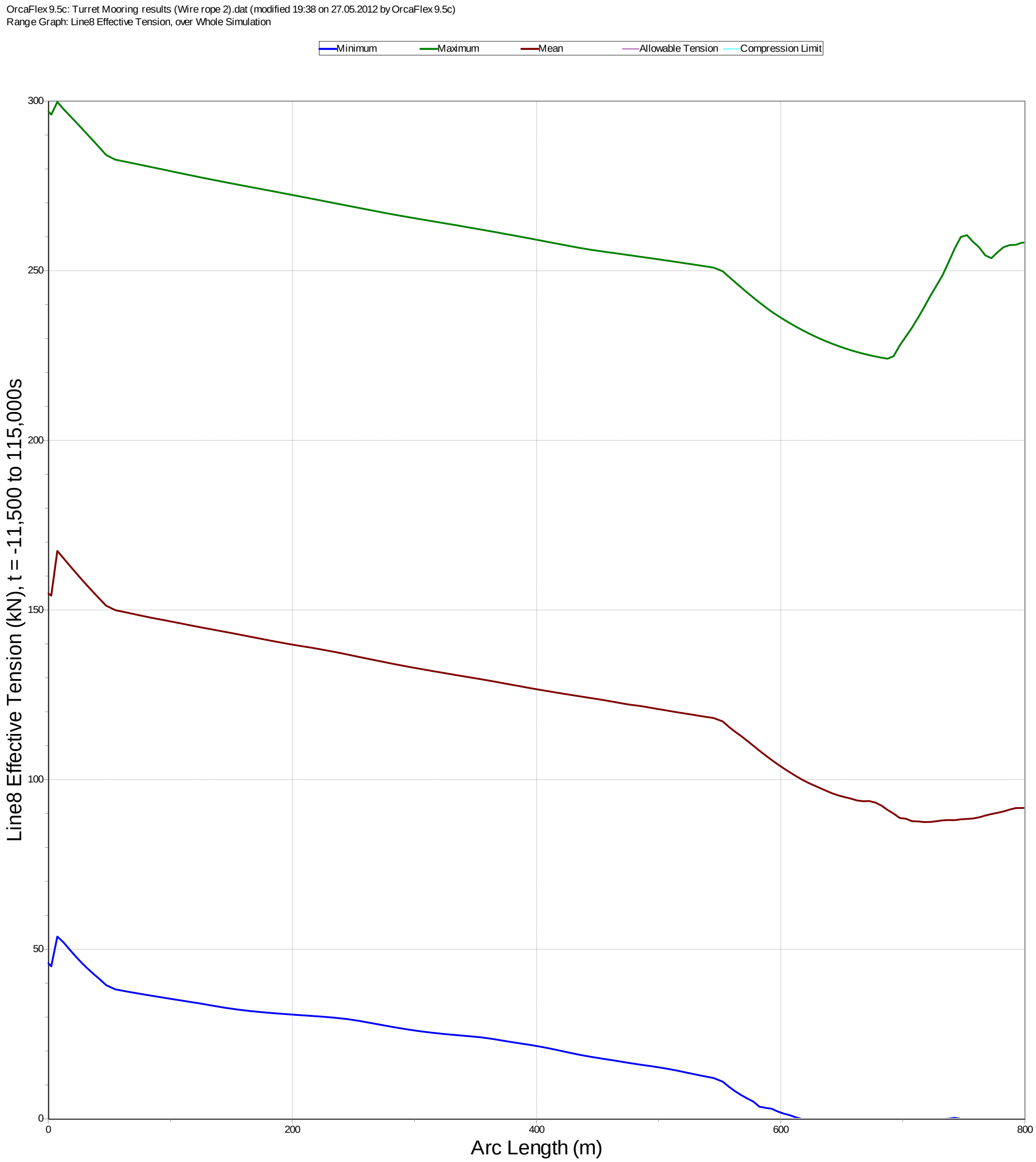


Fig 6.45 Range graph for tension in mooring line 8 (Case 3)

6.4.3 Comparison of results in Case1 , Case 2 and Case 3

The tensions obtained in case 3 are quite high when compared to case1 and case 2 but they are still within acceptable limits as they are less than the minimum breaking loads of both materials as can be seen in Table 6.13 and Table 6.14. The time history values for case 3 are presented in appendix 3-C.

Comparing Case1, Case 2 and Case 3, from the results obtained , it is obvious that the maximum effective tensions in case 3 is the highest followed by case 2 and case 1 has the lowest maximum effective tensions. A barchart showing the difference in the effective tensions for the three cases is shown in Fig 6.47 below. Conclusions and further recommendations are given in Chapter seven.

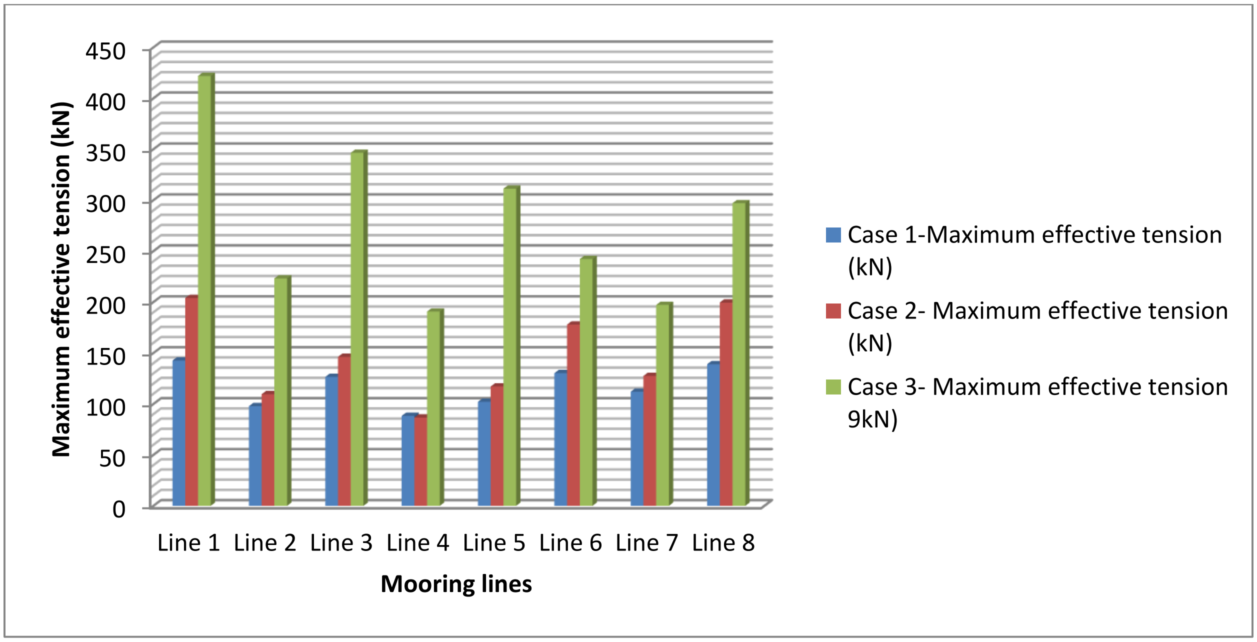


Fig 6.46 Comparison of maximum effective tension for case 1, case 2 and case 3.

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusion

The present study has looked into the analysis of mooring/anchoring systems for offshore vessels in deep waters. A review of the different types of mooring/anchoring systems was firstly carried out, followed by a SWOT analysis. In Chapter three, a review of the important standards and regulation governing the design and installation of mooring systems was presented. Three mooring line configuration cases were considered in this thesis and the results have been presented in chapter six. The characteristics and mechanical properties of mooring line materials were also reviewed and presented in chapter four, to enable us select the best mooring line configuration.

The tensions in the mooring lines were determined by carrying out static and dynamic analysis on the three mooring cases with OrcaFlex software. The prevailing environmental conditions can be observed in the South China Sea. With the requirement to operate in increasing water depths, the suspended weight of mooring lines becomes a prohibitive factor. In particular, steel chains become less attractive at great water depths. This constraint has necessitated the development of synthetic fiber ropes.

From the dynamic analysis carried out in this thesis, we can conclude that chain/fiber rope configuration is the best alternative for deep water mooring applications. The analysis carried out with chain/fiber rope mooring line in Case 1 produced the lowest tension in the mooring lines, when compared to case 2 and case 3. Using fiber rope as part of the mooring configuration will also reduce the total mooring cost.

In conclusion, it is important to state that, an alternative to mooring systems is the Dynamic Positioning (DP) system. The DP systems incorporate active heave compensation systems to achieve station keeping for safe and efficient marine operation activities. Dynamic positioning is a technique of automatically maintaining the position of a floating vessel within a specified tolerance by controlling onboard thrusters which generate thrust vectors to counter the wind, wave and current forces. Dynamic positioning is particularly well suited for a vessel designed to arrive and leave location frequently, such as an extended well test system (API RP 2SK, 2005).

It is also noteworthy to mention that many vessels designed to operate with moorings are also equipped with thrusters and thruster control systems. The thrusters can be used to control the vessel heading, thereby reducing mooring load under severe environmental conditions, or increase the workability of the floating vessel.

7.2 Recommendations

From the results obtained from the different analysis carried out, we will make the following recommendations as regards the choice of mooring/anchoring systems for different offshore applications.

1) It is recommended to use chain as the mooring line for marine operations in shallow waters. The chain will provide good abrasion resistance at the point of contact with the sea floor. Larger catenary is achieved with chains, thereby allowing lateral vessel excursions.The weight of the chain also contributes to the holding capacity of the anchor.
2) For exploration and production in deep to ultra-deep water, the weight of the mooring line starts to become a limiting factor in the design of the floater. To overcome this problem, we recommend the use of polyester synthetic ropes as part of the mooring line. Synthetic fiber rope is characterized by its high strength to weight ratio. Employing fiber rope as part of the mooring line configuration will increase the flexibility of the mooring line, reduce the tension and consequently reduce the mooring cost.
3) Wire rope can replace fiber rope in sea environments where the fiber ropes are susceptible to fish bite. This will guarantee the safety of the mooring system.
4) Drag embedment anchors should always be used for deep water applications where enormous horizontal loads are imposed on the mooring lines. The anchor is very well suited for resisting large horizontal loads.
5) Vertical Load Anchors (VLA) should be used with the mooring lines in situations where the mooring line is expected to resist both vertical and horizontal loads. VLA penetrates much deeper into the soil. When the anchor mode is changed from the installation mode to the vertical (normal) loading mode, the anchor can withstand both horizontal and vertical loads. VLA’s should be used with taut leg mooring systems because the vertical load requirements are high.

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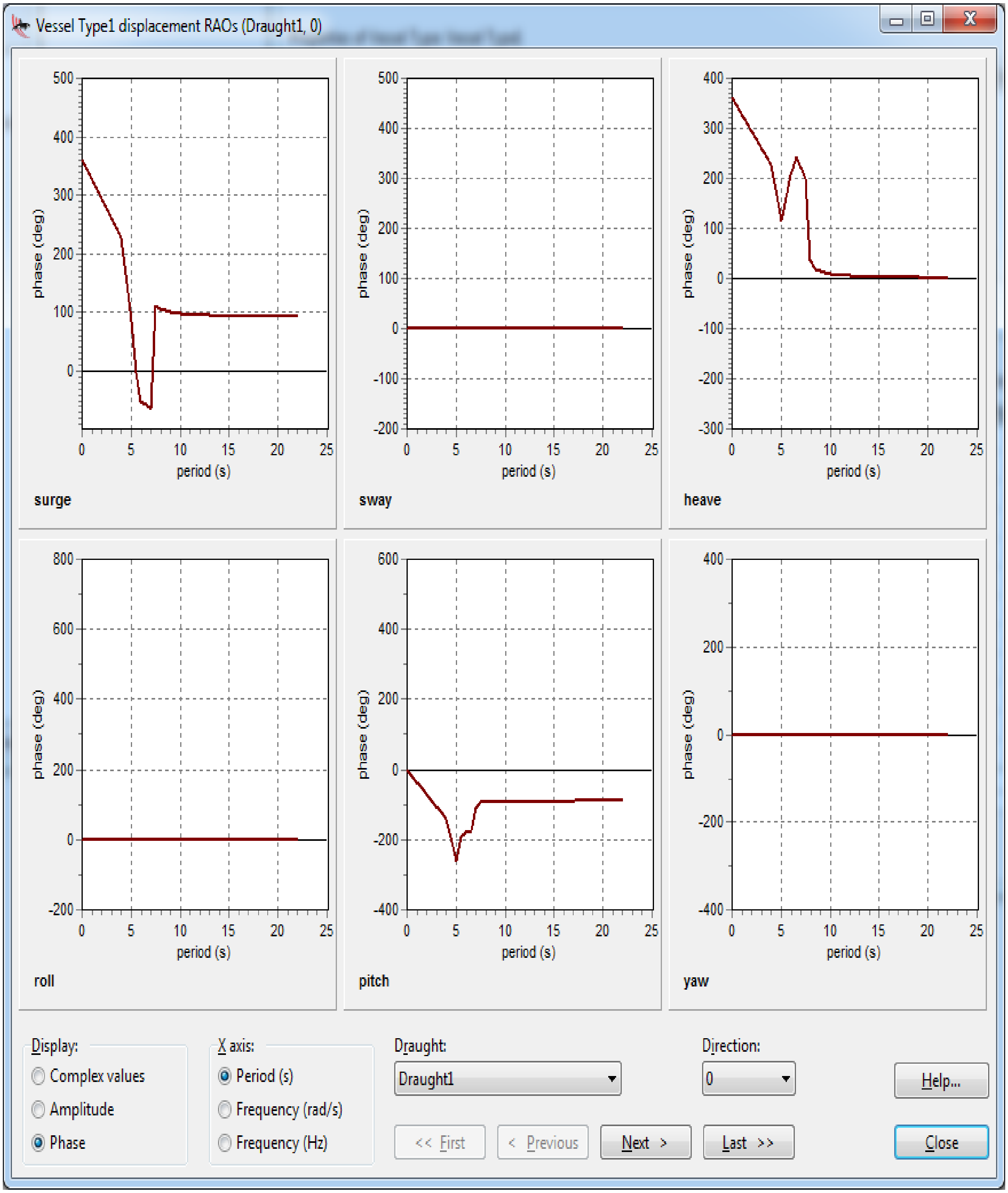
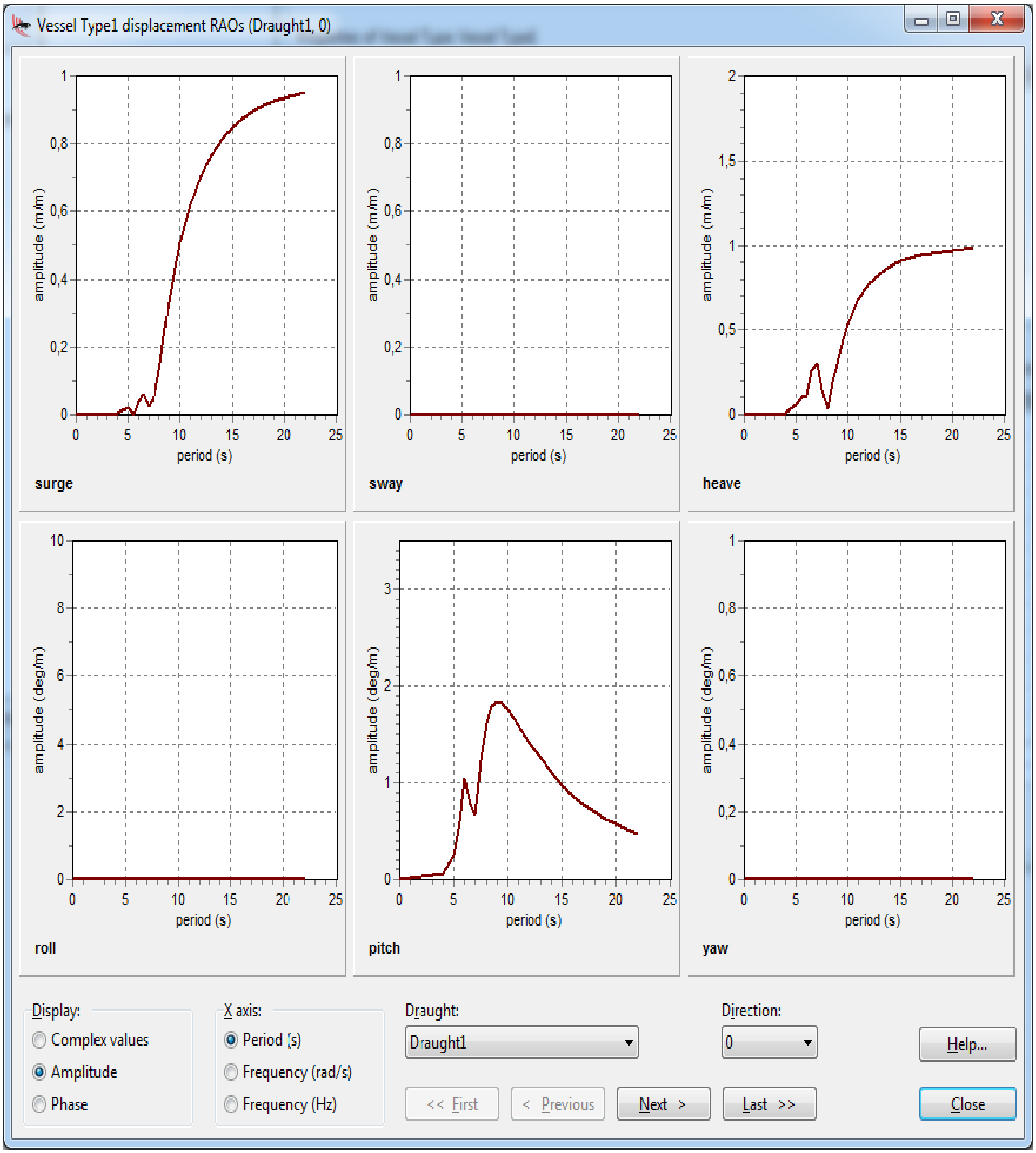
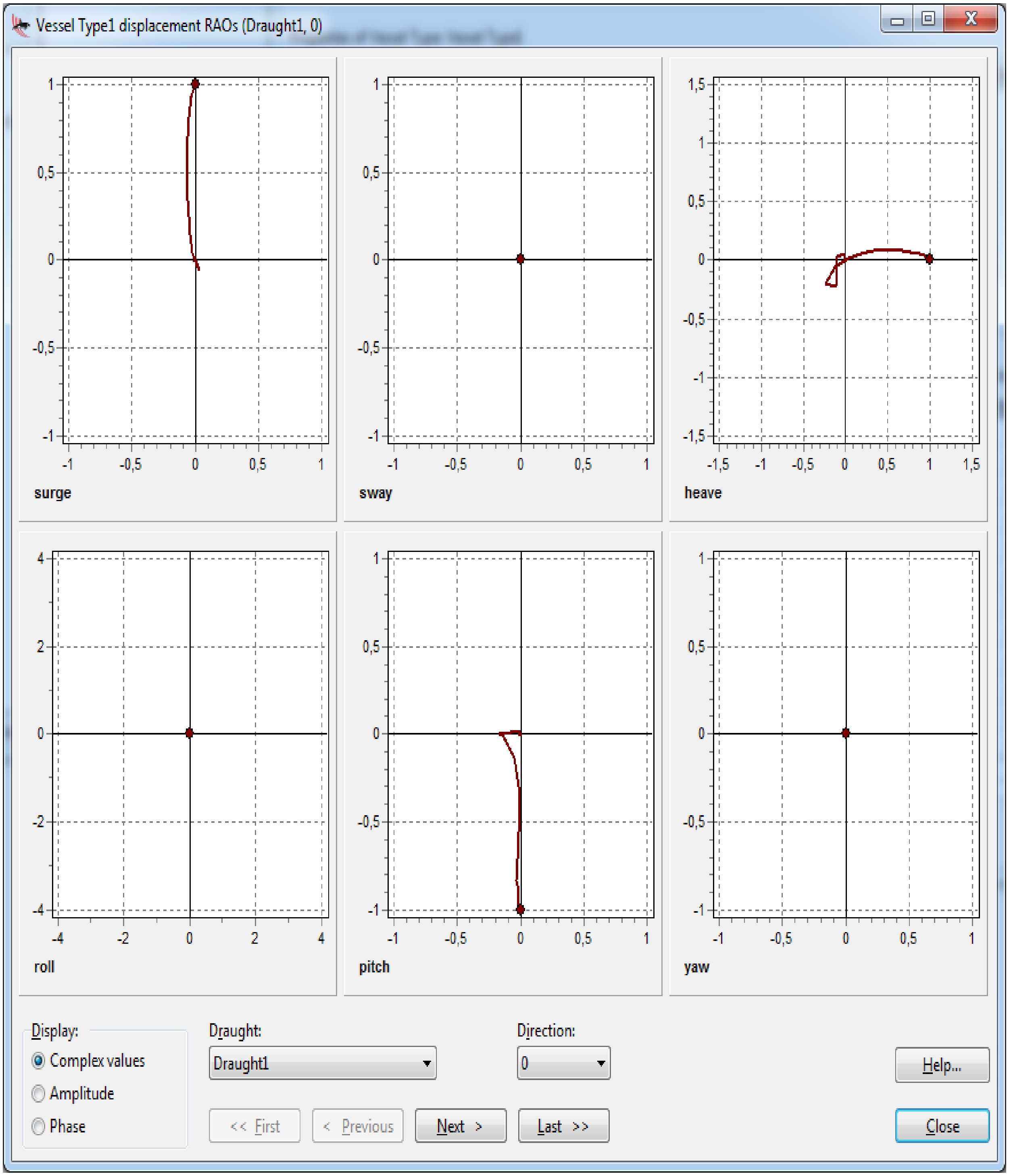
Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



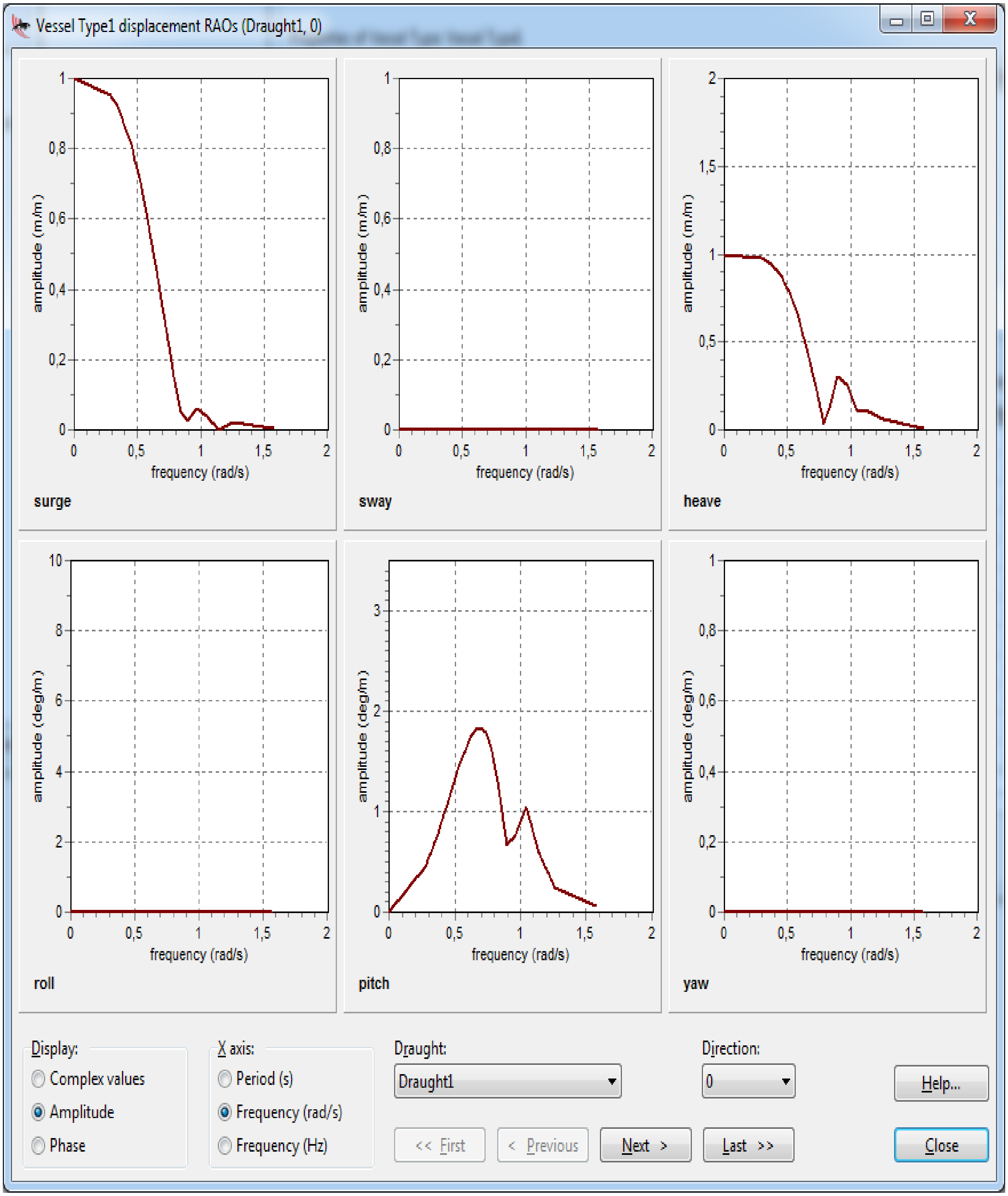
Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



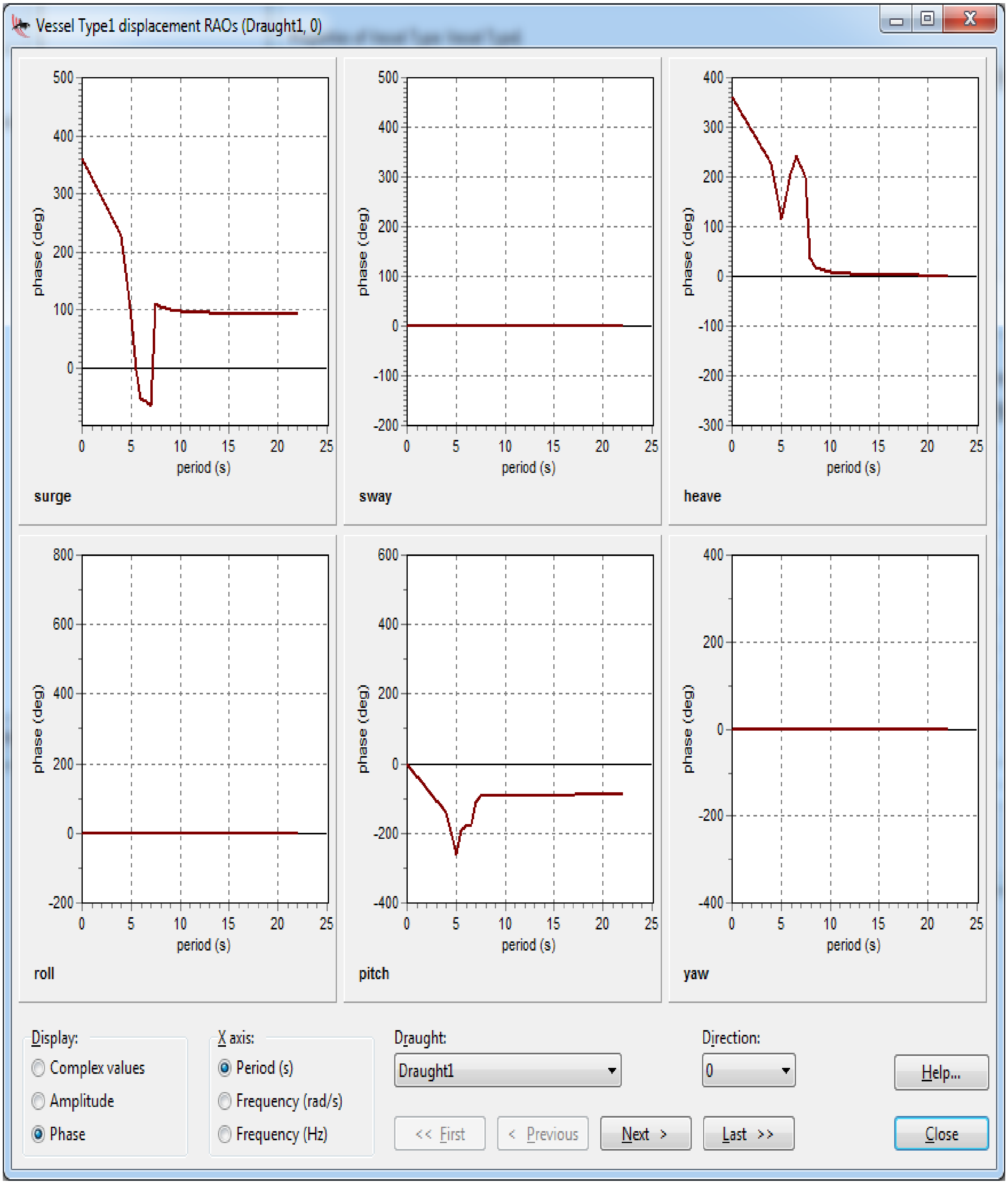
Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



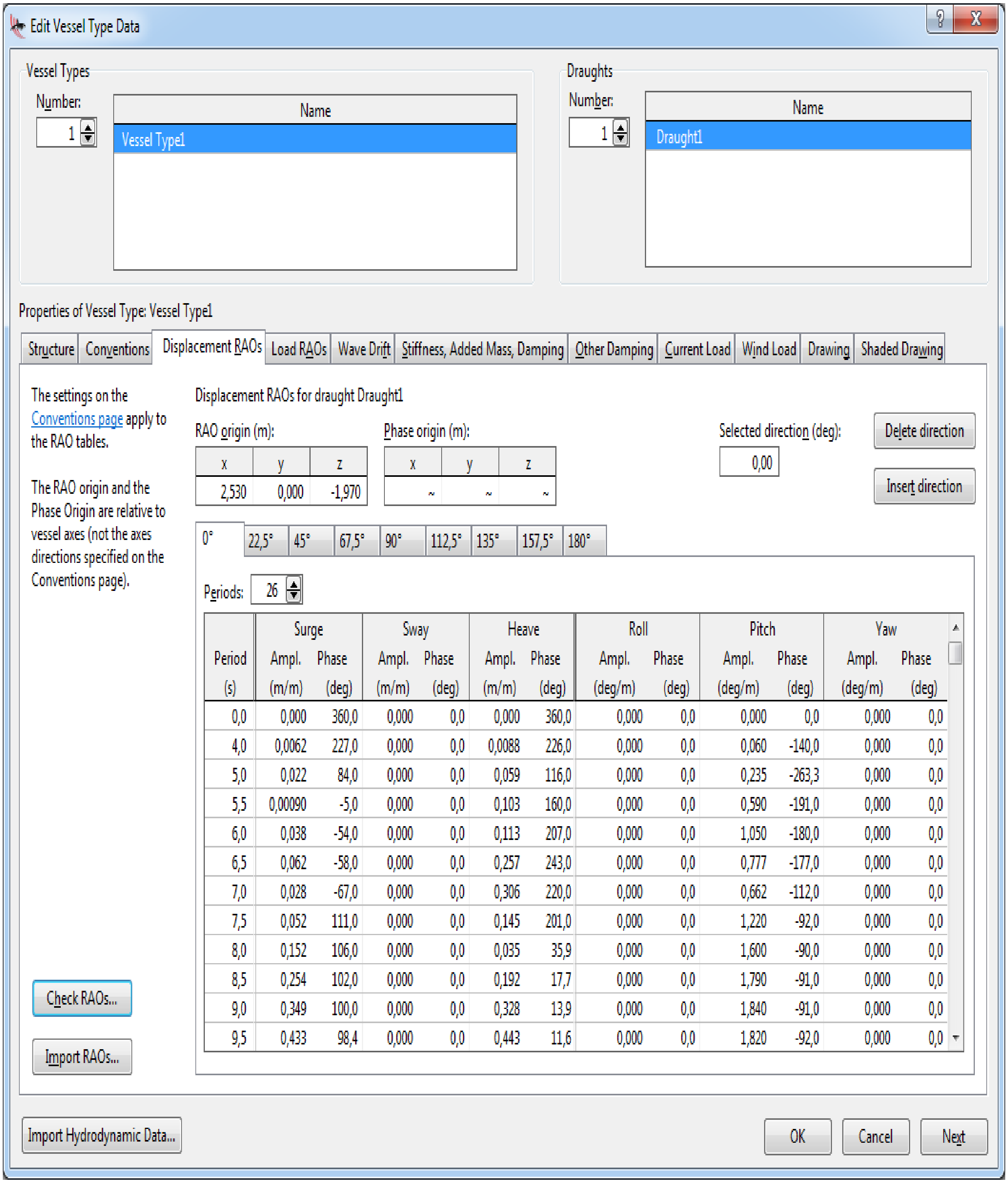
Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3

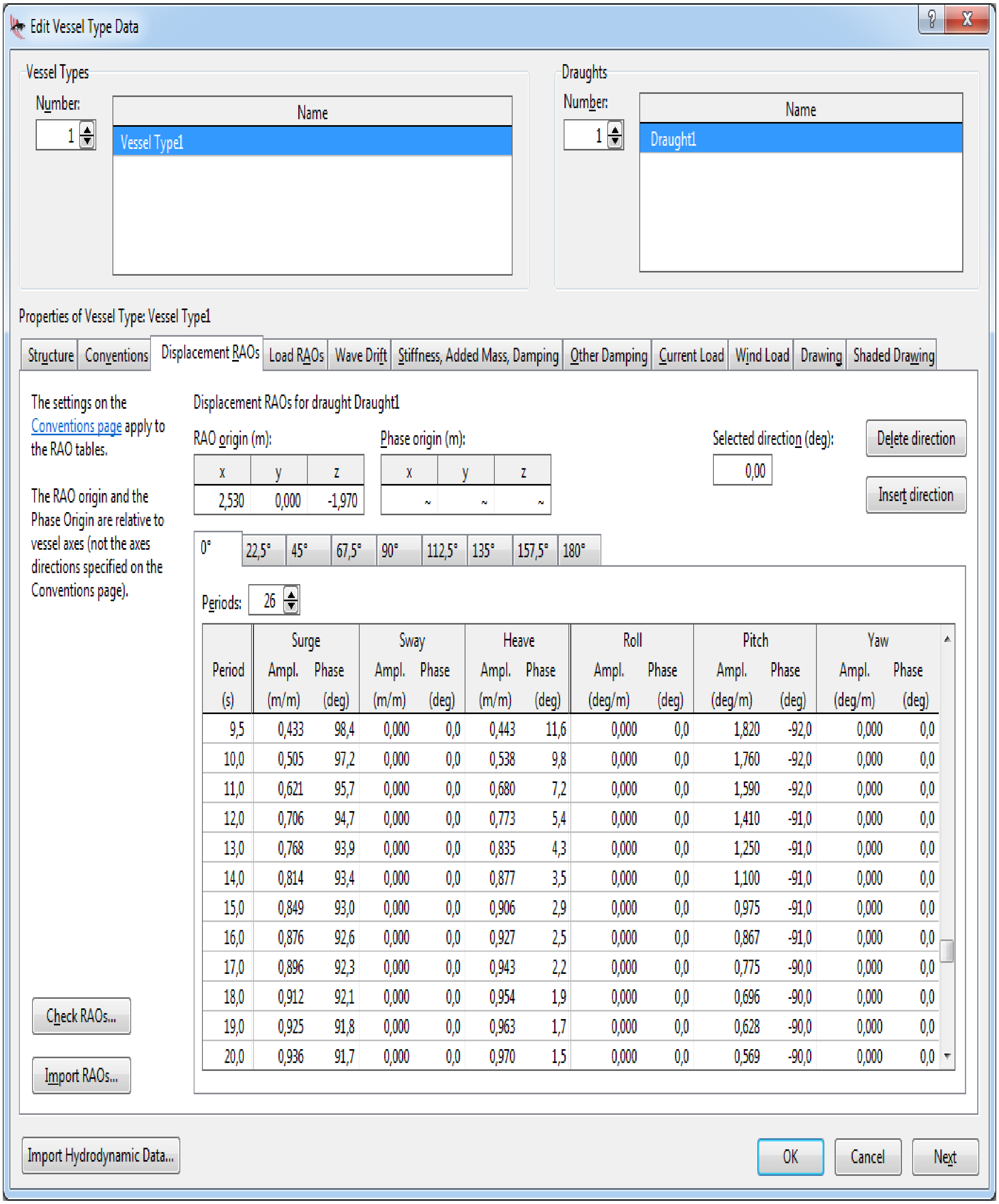


Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



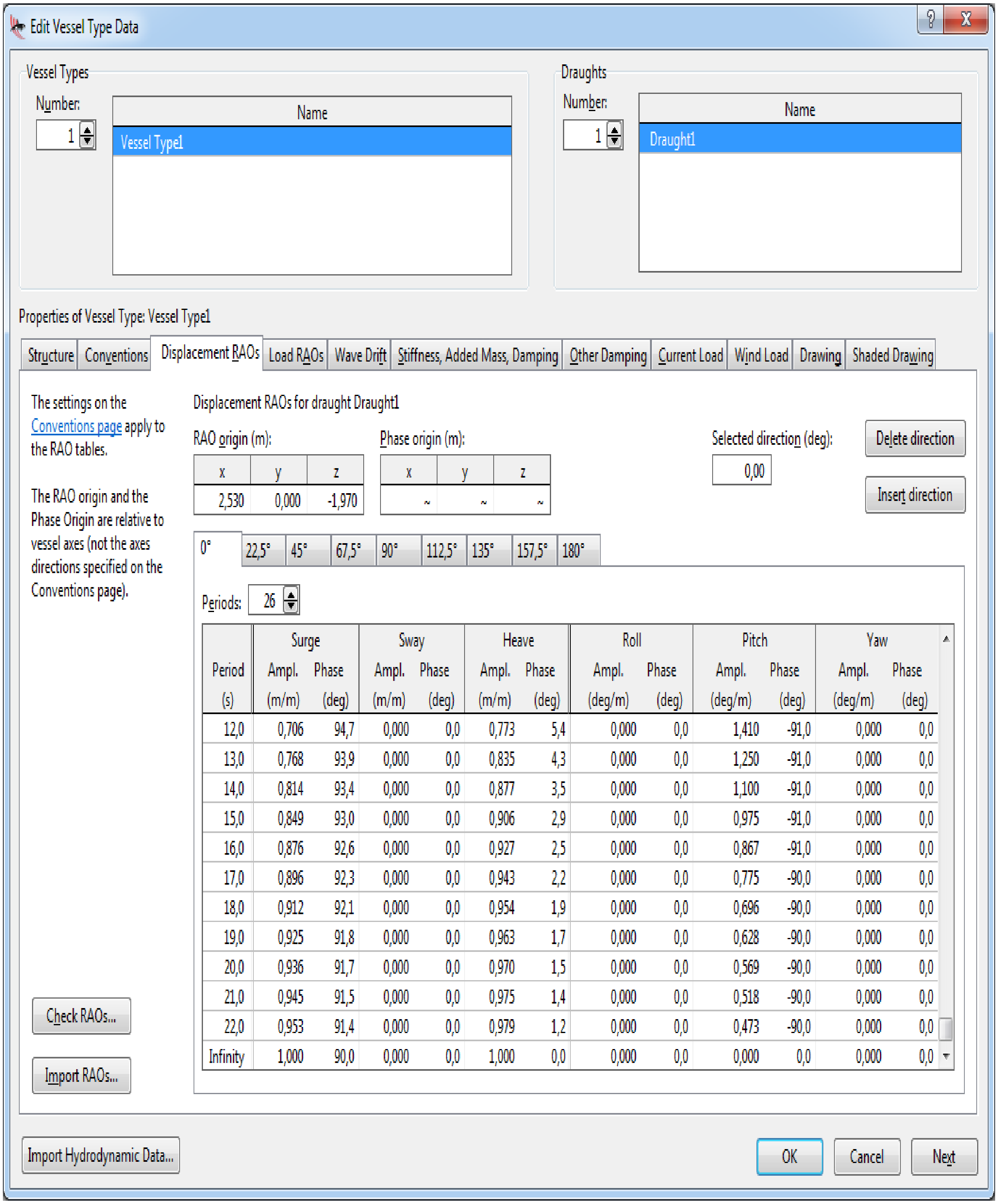
	Surge		Sway		Heave		Roll		Pitch		Yaw	
Period (s)	Ampl. (m/m)	Phase (deg)	Ampl. (m/m)	Phase (deg)	Ampl. (m/m)	Phase (deg)	Ampl. (deg/m)	Phase (deg)	Ampl. (deg/m)	Phase (deg)	Ampl. (deg/m)	Phase (deg)
0,0	0,000	360,0	0,000	0,0	0,000	360,0	0,000	0,0	0,000	0,0	0,000	0,0
4,0	0,0062	227,0	0,000	0,0	0,0088	226,0	0,000	0,0	0,060	-140,0	0,000	0,0
5,0	0,022	84,0	0,000	0,0	0,059	116,0	0,000	0,0	0,235	-263,3	0,000	0,0
5,5	0,00090	-5,0	0,000	0,0	0,103	160,0	0,000	0,0	0,590	-191,0	0,000	0,0
6,0	0,038	-54,0	0,000	0,0	0,113	207,0	0,000	0,0	1,050	-180,0	0,000	0,0
6,5	0,062	-58,0	0,000	0,0	0,257	243,0	0,000	0,0	0,777	-177,0	0,000	0,0
7,0	0,028	-67,0	0,000	0,0	0,306	220,0	0,000	0,0	0,662	-112,0	0,000	0,0
7,5	0,052	111,0	0,000	0,0	0,145	201,0	0,000	0,0	1,220	-92,0	0,000	0,0
8,0	0,152	106,0	0,000	0,0	0,035	35,9	0,000	0,0	1,600	-90,0	0,000	0,0
8,5	0,254	102,0	0,000	0,0	0,192	17,7	0,000	0,0	1,790	-91,0	0,000	0,0
9,0	0,349	100,0	0,000	0,0	0,328	13,9	0,000	0,0	1,840	-91,0	0,000	0,0
9,5	0,433	98,4	0,000	0,0	0,443	11,6	0,000	0,0	1,820	-92,0	0,000	0,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



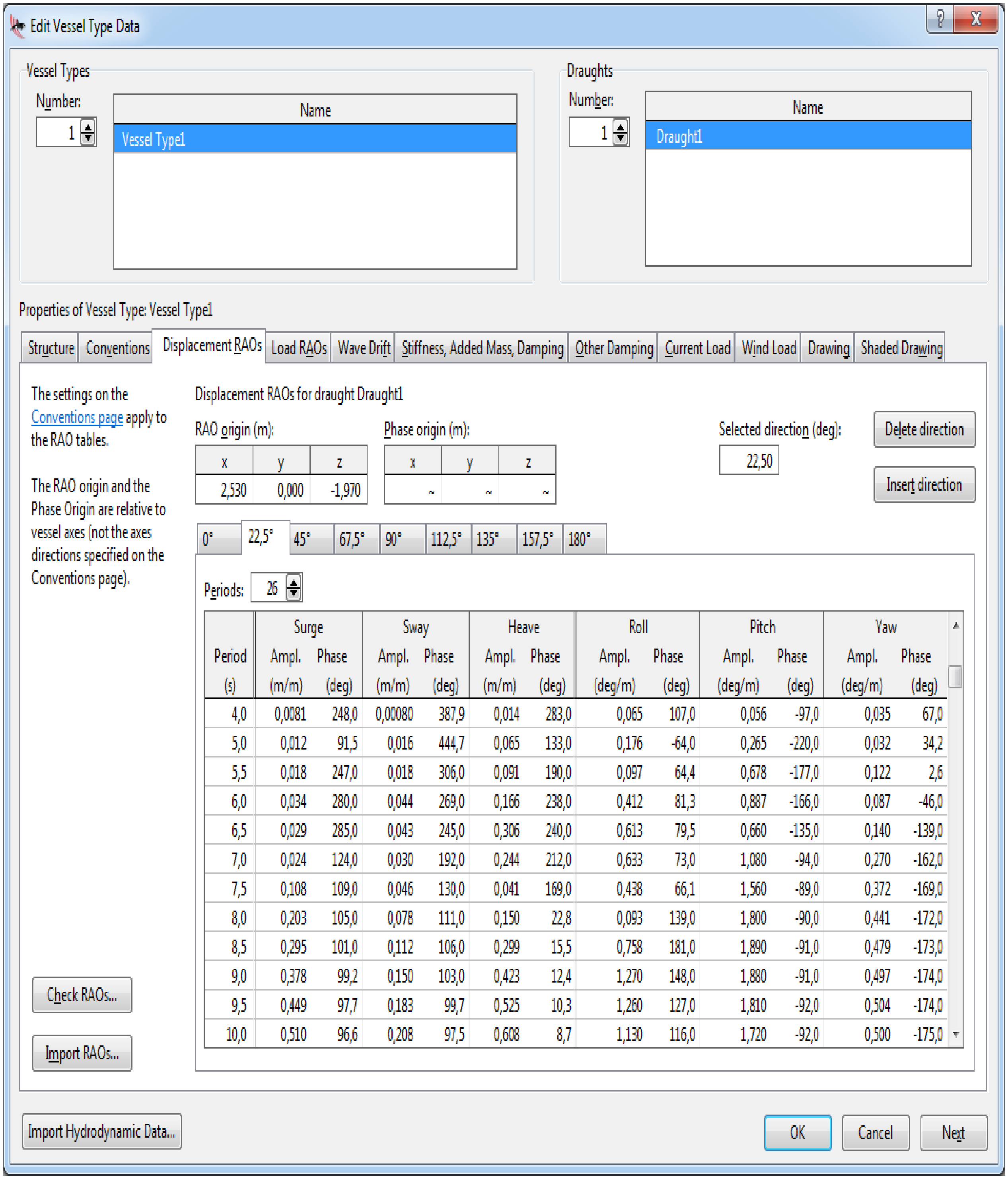
Period	Surge		Sway		Heave		Roll		Pitch		Yaw	
	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase
(s)	(m/m)	(deg)	(m/m)	(deg)	(m/m)	(deg)	(deg/m)	(deg)	(deg/m)	(deg)	(deg/m)	(deg)
9,5	0,433	98,4	0,000	0,0	0,443	11,6	0,000	0,0	1,820	-92,0	0,000	0,0
10,0	0,505	97,2	0,000	0,0	0,538	9,8	0,000	0,0	1,760	-92,0	0,000	0,0
11,0	0,621	95,7	0,000	0,0	0,680	7,2	0,000	0,0	1,590	-92,0	0,000	0,0
12,0	0,706	94,7	0,000	0,0	0,773	5,4	0,000	0,0	1,410	-91,0	0,000	0,0
13,0	0,768	93,9	0,000	0,0	0,835	4,3	0,000	0,0	1,250	-91,0	0,000	0,0
14,0	0,814	93,4	0,000	0,0	0,877	3,5	0,000	0,0	1,100	-91,0	0,000	0,0
15,0	0,849	93,0	0,000	0,0	0,906	2,9	0,000	0,0	0,975	-91,0	0,000	0,0
16,0	0,876	92,6	0,000	0,0	0,927	2,5	0,000	0,0	0,867	-91,0	0,000	0,0
17,0	0,896	92,3	0,000	0,0	0,943	2,2	0,000	0,0	0,775	-90,0	0,000	0,0
18,0	0,912	92,1	0,000	0,0	0,954	1,9	0,000	0,0	0,696	-90,0	0,000	0,0
19,0	0,925	91,8	0,000	0,0	0,963	1,7	0,000	0,0	0,628	-90,0	0,000	0,0
20,0	0,936	91,7	0,000	0,0	0,970	1,5	0,000	0,0	0,569	-90,0	0,000	0,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



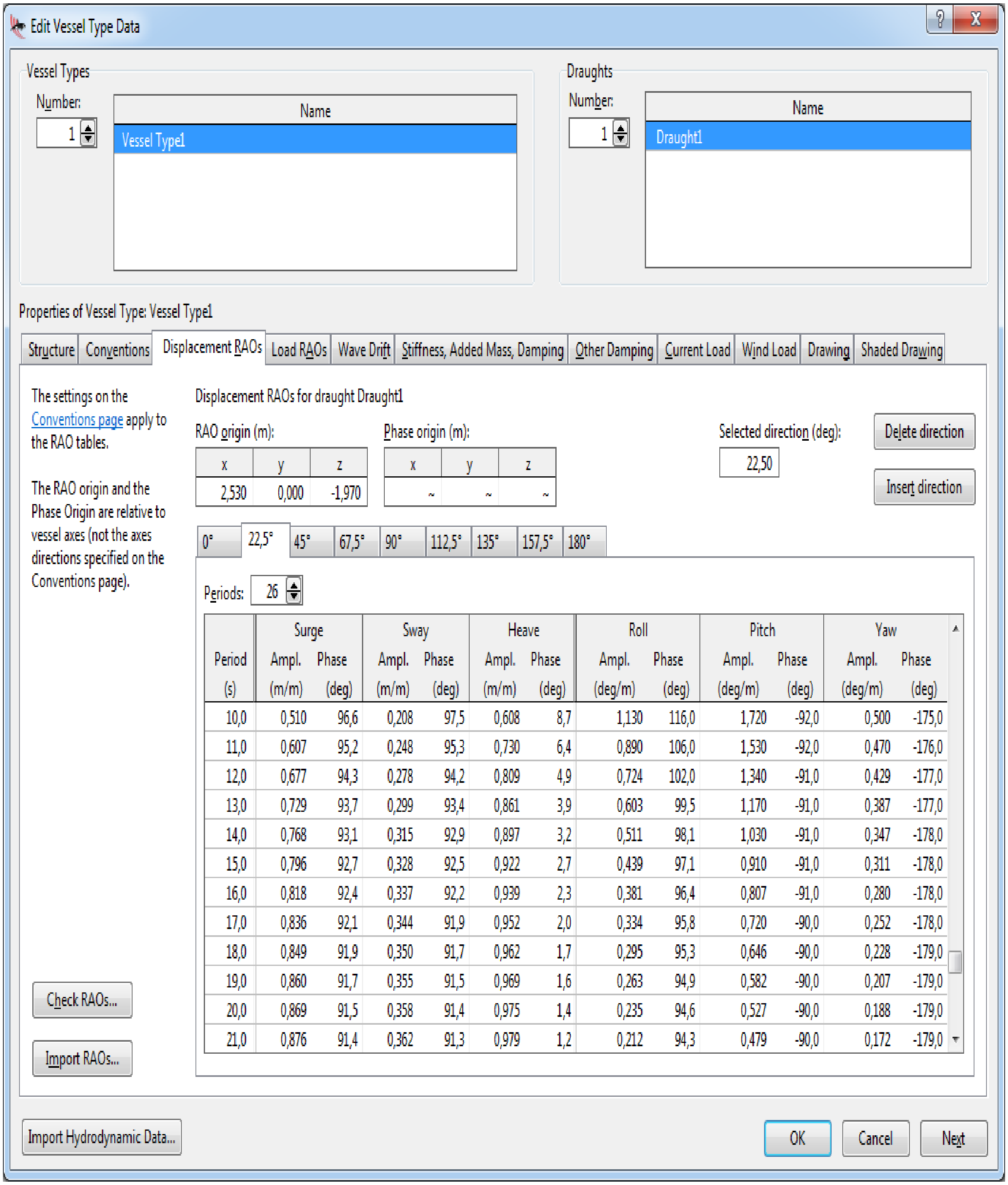
Period (s)	Surge Ampl. (m/m)	Surge Phase (deg)	Sway Ampl. (m/m)	Sway Phase (deg)	Heave Ampl. (m/m)	Heave Phase (deg)	Roll Ampl. (deg/m)	Roll Phase (deg)	Pitch Ampl. (deg/m)	Pitch Phase (deg)	Yaw Ampl. (deg/m)	Yaw Phase (deg)
12,0	0,706	94,7	0,000	0,0	0,773	5,4	0,000	0,0	1,410	-91,0	0,000	0,0
13,0	0,768	93,9	0,000	0,0	0,835	4,3	0,000	0,0	1,250	-91,0	0,000	0,0
14,0	0,814	93,4	0,000	0,0	0,877	3,5	0,000	0,0	1,100	-91,0	0,000	0,0
15,0	0,849	93,0	0,000	0,0	0,906	2,9	0,000	0,0	0,975	-91,0	0,000	0,0
16,0	0,876	92,6	0,000	0,0	0,927	2,5	0,000	0,0	0,867	-91,0	0,000	0,0
17,0	0,896	92,3	0,000	0,0	0,943	2,2	0,000	0,0	0,775	-90,0	0,000	0,0
18,0	0,912	92,1	0,000	0,0	0,954	1,9	0,000	0,0	0,696	-90,0	0,000	0,0
19,0	0,925	91,8	0,000	0,0	0,963	1,7	0,000	0,0	0,628	-90,0	0,000	0,0
20,0	0,936	91,7	0,000	0,0	0,970	1,5	0,000	0,0	0,569	-90,0	0,000	0,0
21,0	0,945	91,5	0,000	0,0	0,975	1,4	0,000	0,0	0,518	-90,0	0,000	0,0
22,0	0,953	91,4	0,000	0,0	0,979	1,2	0,000	0,0	0,473	-90,0	0,000	0,0
Infinity	1,000	90,0	0,000	0,0	1,000	0,0	0,000	0,0	0,000	0,0	0,000	0,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



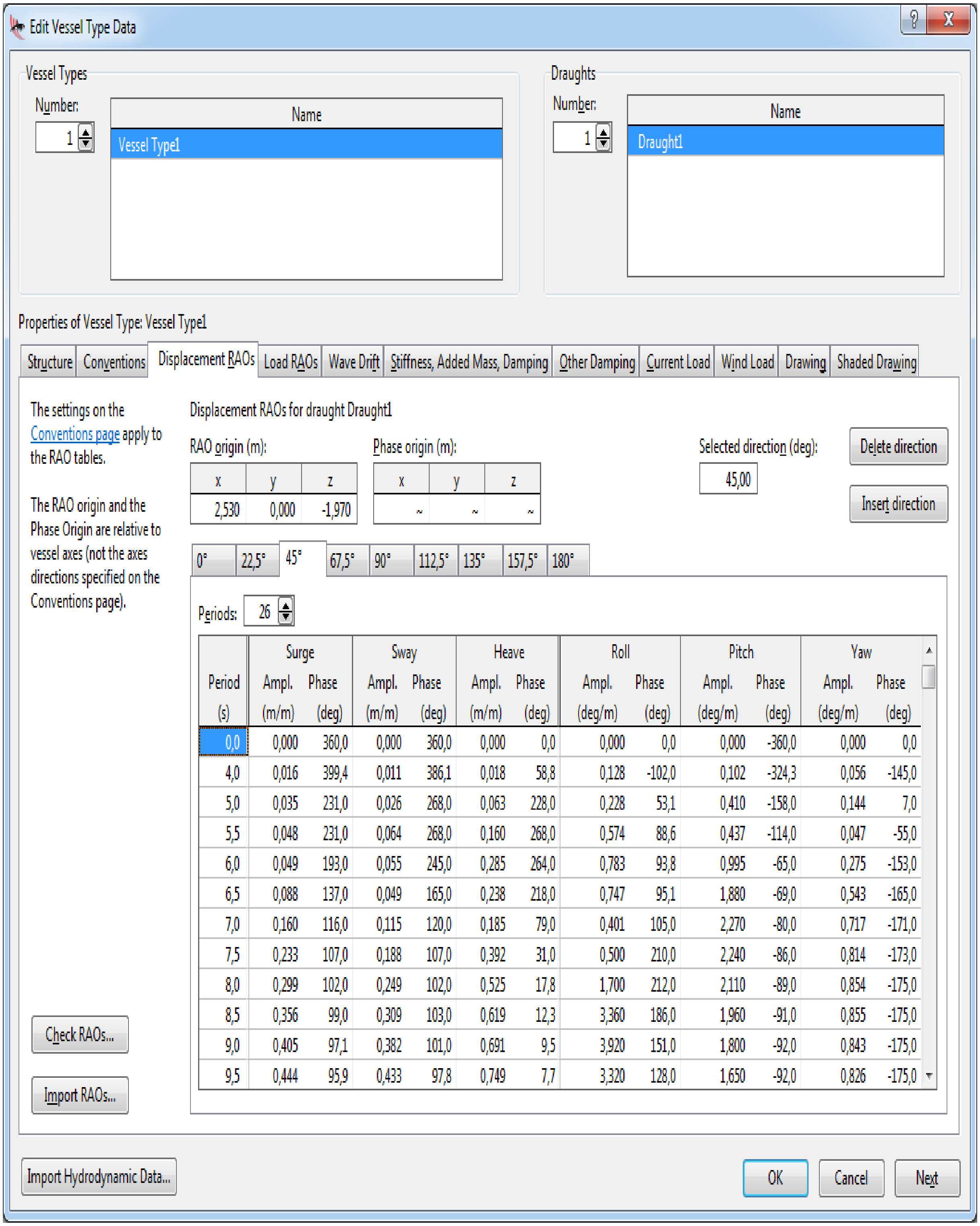
Period (s)	Surge Ampl. (m/m)	Surge Phase (deg)	Sway Ampl. (m/m)	Sway Phase (deg)	Heave Ampl. (m/m)	Heave Phase (deg)	Roll Ampl. (deg/m)	Roll Phase (deg)	Pitch Ampl. (deg/m)	Pitch Phase (deg)	Yaw Ampl. (deg/m)	Yaw Phase (deg)
4,0	0,0081	248,0	0,00080	387,9	0,014	283,0	0,065	107,0	0,056	-97,0	0,035	67,0
5,0	0,012	91,5	0,016	444,7	0,065	133,0	0,176	-64,0	0,265	-220,0	0,032	34,2
5,5	0,018	247,0	0,018	306,0	0,091	190,0	0,097	64,4	0,678	-177,0	0,122	2,6
6,0	0,034	280,0	0,044	269,0	0,166	238,0	0,412	81,3	0,887	-166,0	0,087	-46,0
6,5	0,029	285,0	0,043	245,0	0,306	240,0	0,613	79,5	0,660	-135,0	0,140	-139,0
7,0	0,024	124,0	0,030	192,0	0,244	212,0	0,633	73,0	1,080	-94,0	0,270	-162,0
7,5	0,108	109,0	0,046	130,0	0,041	169,0	0,438	66,1	1,560	-89,0	0,372	-169,0
8,0	0,203	105,0	0,078	111,0	0,150	22,8	0,093	139,0	1,800	-90,0	0,441	-172,0
8,5	0,295	101,0	0,112	106,0	0,299	15,5	0,758	181,0	1,890	-91,0	0,479	-173,0
9,0	0,378	99,2	0,150	103,0	0,423	12,4	1,270	148,0	1,880	-91,0	0,497	-174,0
9,5	0,449	97,7	0,183	99,7	0,525	10,3	1,260	127,0	1,810	-92,0	0,504	-174,0
10,0	0,510	96,6	0,208	97,5	0,608	8,7	1,130	116,0	1,720	-92,0	0,500	-175,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



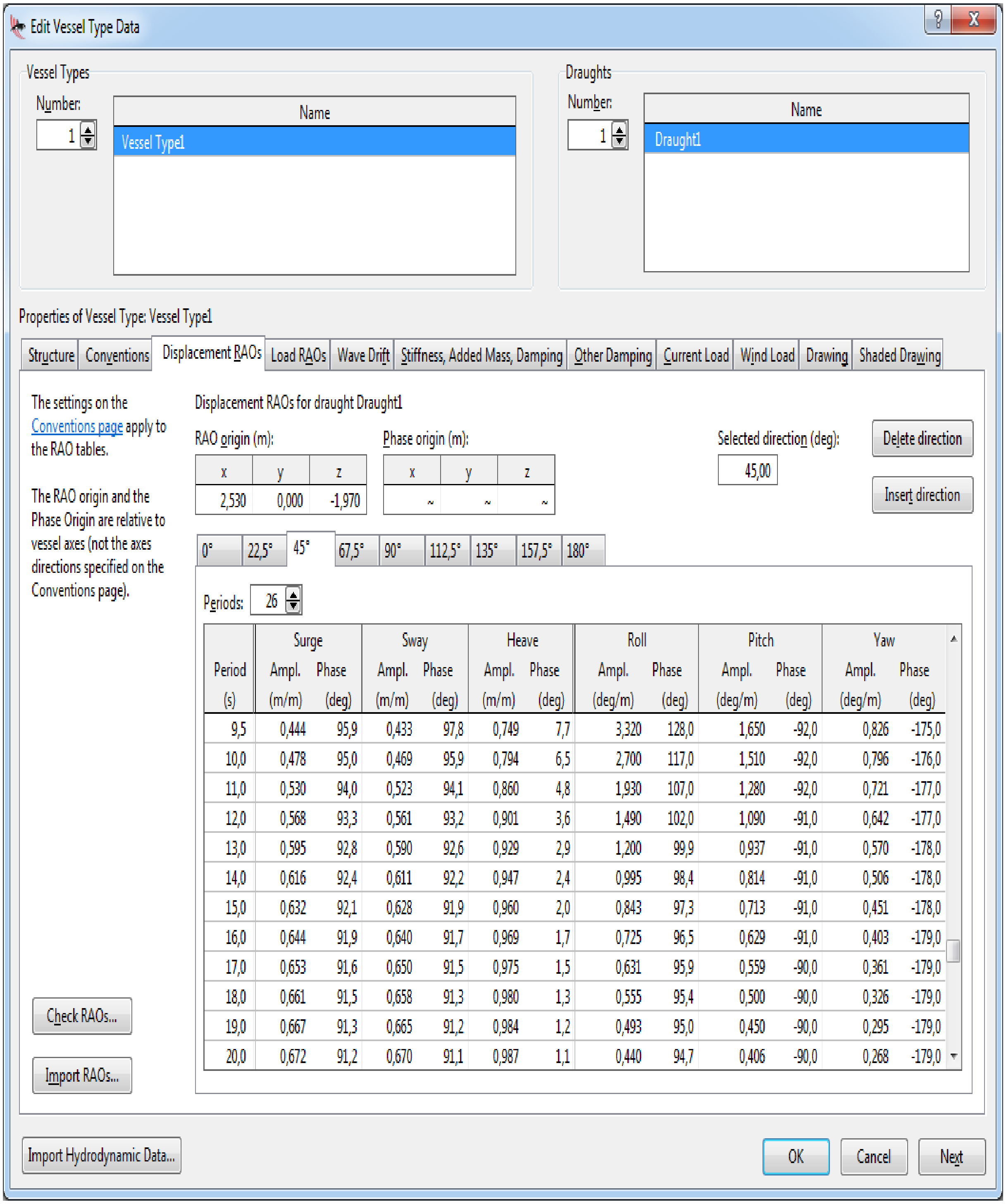
Period (s)	Surge Ampl. (m/m)	Surge Phase (deg)	Sway Ampl. (m/m)	Sway Phase (deg)	Heave Ampl. (m/m)	Heave Phase (deg)	Roll Ampl. (deg/m)	Roll Phase (deg)	Pitch Ampl. (deg/m)	Pitch Phase (deg)	Yaw Ampl. (deg/m)	Yaw Phase (deg)
10,0	0,510	96,6	0,208	97,5	0,608	8,7	1,130	116,0	1,720	-92,0	0,500	-175,0
11,0	0,607	95,2	0,248	95,3	0,730	6,4	0,890	106,0	1,530	-92,0	0,470	-176,0
12,0	0,677	94,3	0,278	94,2	0,809	4,9	0,724	102,0	1,340	-91,0	0,429	-177,0
13,0	0,729	93,7	0,299	93,4	0,861	3,9	0,603	99,5	1,170	-91,0	0,387	-177,0
14,0	0,768	93,1	0,315	92,9	0,897	3,2	0,511	98,1	1,030	-91,0	0,347	-178,0
15,0	0,796	92,7	0,328	92,5	0,922	2,7	0,439	97,1	0,910	-91,0	0,311	-178,0
16,0	0,818	92,4	0,337	92,2	0,939	2,3	0,381	96,4	0,807	-91,0	0,280	-178,0
17,0	0,836	92,1	0,344	91,9	0,952	2,0	0,334	95,8	0,720	-90,0	0,252	-178,0
18,0	0,849	91,9	0,350	91,7	0,962	1,7	0,295	95,3	0,646	-90,0	0,228	-179,0
19,0	0,860	91,7	0,355	91,5	0,969	1,6	0,263	94,9	0,582	-90,0	0,207	-179,0
20,0	0,869	91,5	0,358	91,4	0,975	1,4	0,235	94,6	0,527	-90,0	0,188	-179,0
21,0	0,876	91,4	0,362	91,3	0,979	1,2	0,212	94,3	0,479	-90,0	0,172	-179,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



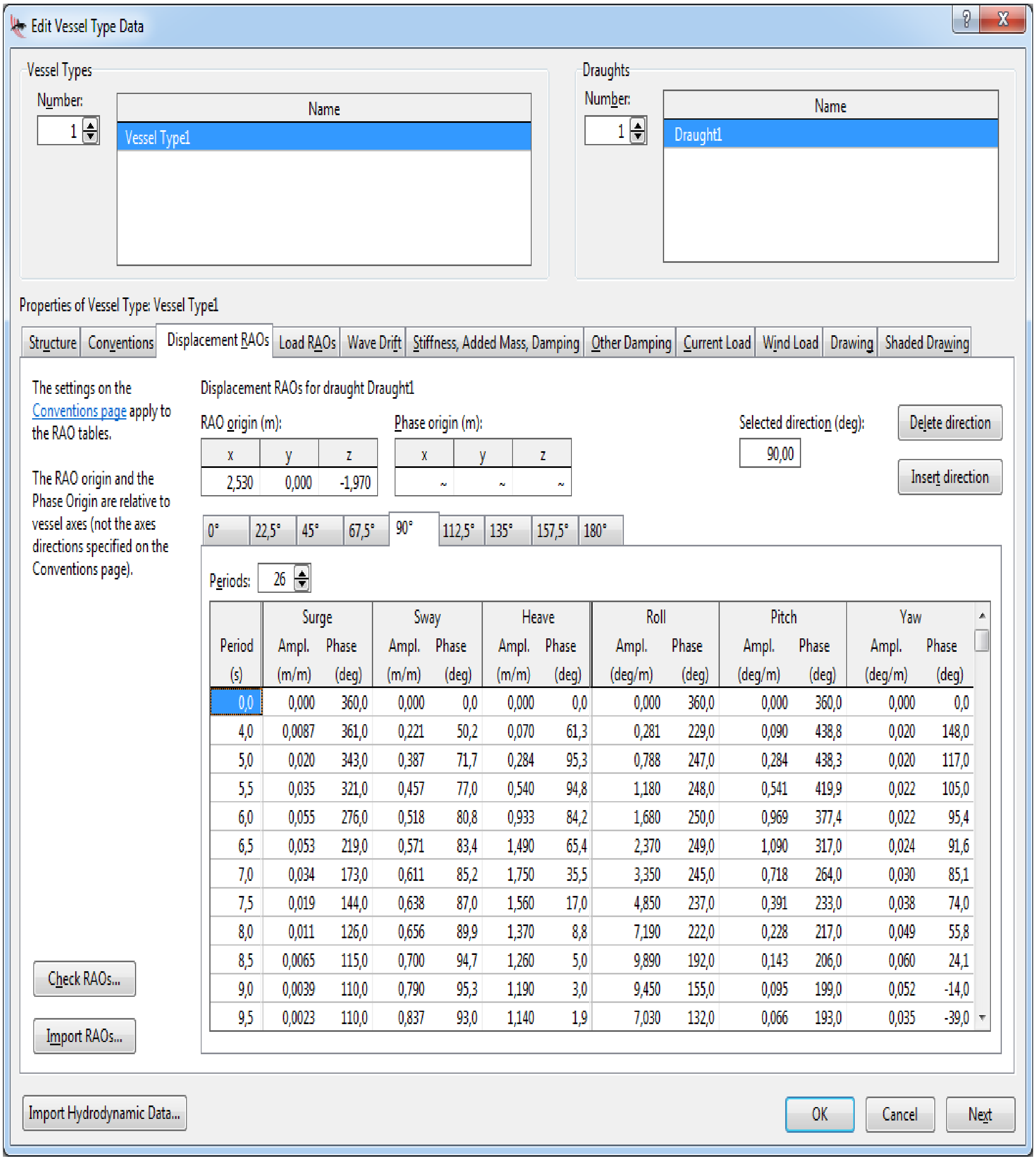
Period	Surge		Sway		Heave		Roll		Pitch		Yaw	
	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase
(s)	(m/m)	(deg)	(m/m)	(deg)	(m/m)	(deg)	(deg/m)	(deg)	(deg/m)	(deg)	(deg/m)	(deg)
0,0	0,000	360,0	0,000	360,0	0,000	0,0	0,000	0,0	0,000	-360,0	0,000	0,0
4,0	0,016	399,4	0,011	386,1	0,018	58,8	0,128	-102,0	0,102	-324,3	0,056	-145,0
5,0	0,035	231,0	0,026	268,0	0,063	228,0	0,228	53,1	0,410	-158,0	0,144	7,0
5,5	0,048	231,0	0,064	268,0	0,160	268,0	0,574	88,6	0,437	-114,0	0,047	-55,0
6,0	0,049	193,0	0,055	245,0	0,285	264,0	0,783	93,8	0,995	-65,0	0,275	-153,0
6,5	0,088	137,0	0,049	165,0	0,238	218,0	0,747	95,1	1,880	-69,0	0,543	-165,0
7,0	0,160	116,0	0,115	120,0	0,185	79,0	0,401	105,0	2,270	-80,0	0,717	-171,0
7,5	0,233	107,0	0,188	107,0	0,392	31,0	0,500	210,0	2,240	-86,0	0,814	-173,0
8,0	0,299	102,0	0,249	102,0	0,525	17,8	1,700	212,0	2,110	-89,0	0,854	-175,0
8,5	0,356	99,0	0,309	103,0	0,619	12,3	3,360	186,0	1,960	-91,0	0,855	-175,0
9,0	0,405	97,1	0,382	101,0	0,691	9,5	3,920	151,0	1,800	-92,0	0,843	-175,0
9,5	0,444	95,9	0,433	97,8	0,749	7,7	3,320	128,0	1,650	-92,0	0,826	-175,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



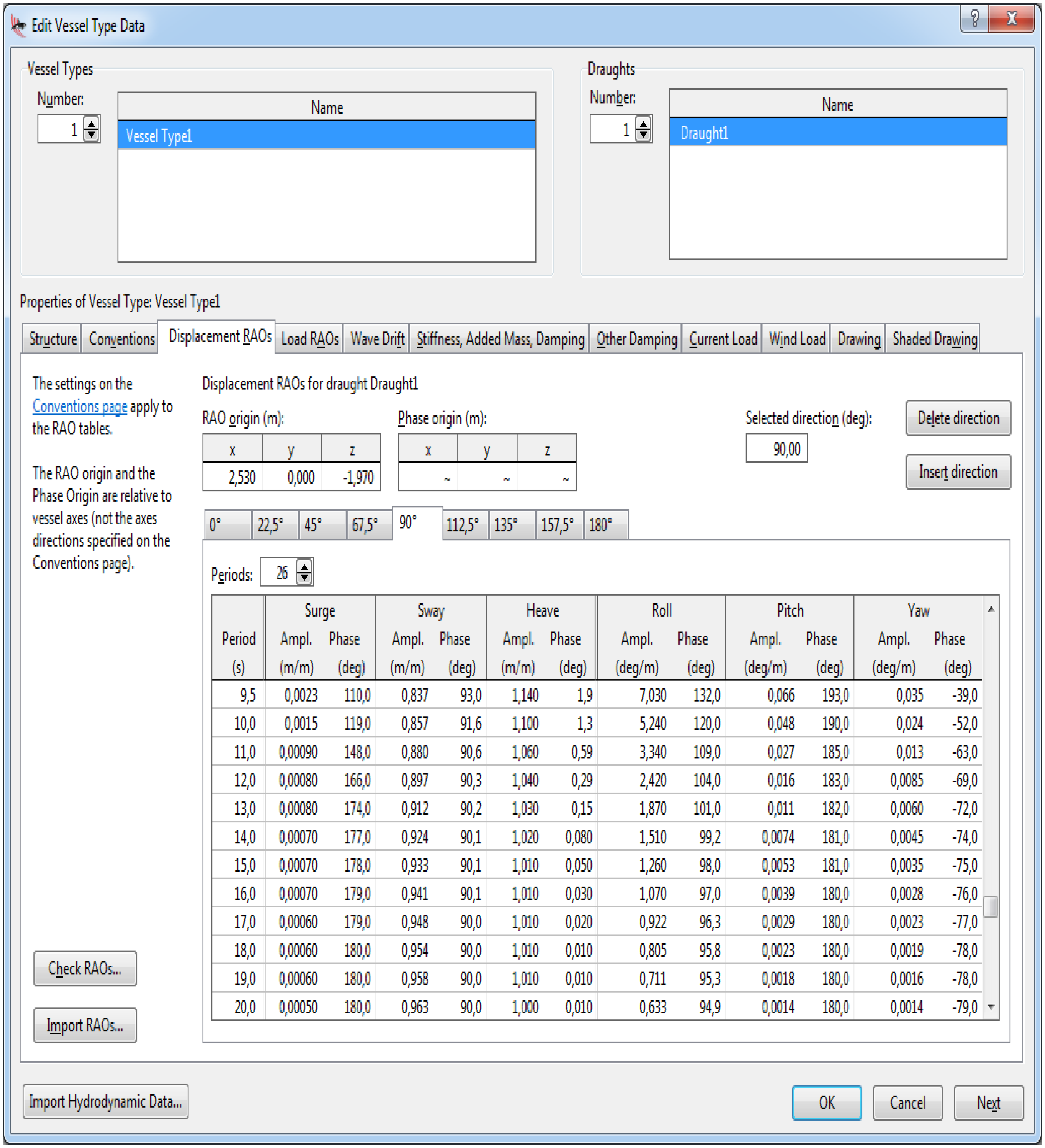
Period (s)	Surge Ampl. (m/m)	Surge Phase (deg)	Sway Ampl. (m/m)	Sway Phase (deg)	Heave Ampl. (m/m)	Heave Phase (deg)	Roll Ampl. (deg/m)	Roll Phase (deg)	Pitch Ampl. (deg/m)	Pitch Phase (deg)	Yaw Ampl. (deg/m)	Yaw Phase (deg)
9,5	0,444	95,9	0,433	97,8	0,749	7,7	3,320	128,0	1,650	-92,0	0,826	-175,0
10,0	0,478	95,0	0,469	95,9	0,794	6,5	2,700	117,0	1,510	-92,0	0,796	-176,0
11,0	0,530	94,0	0,523	94,1	0,860	4,8	1,930	107,0	1,280	-92,0	0,721	-177,0
12,0	0,568	93,3	0,561	93,2	0,901	3,6	1,490	102,0	1,090	-91,0	0,642	-177,0
13,0	0,595	92,8	0,590	92,6	0,929	2,9	1,200	99,9	0,937	-91,0	0,570	-178,0
14,0	0,616	92,4	0,611	92,2	0,947	2,4	0,995	98,4	0,814	-91,0	0,506	-178,0
15,0	0,632	92,1	0,628	91,9	0,960	2,0	0,843	97,3	0,713	-91,0	0,451	-178,0
16,0	0,644	91,9	0,640	91,7	0,969	1,7	0,725	96,5	0,629	-91,0	0,403	-179,0
17,0	0,653	91,6	0,650	91,5	0,975	1,5	0,631	95,9	0,559	-90,0	0,361	-179,0
18,0	0,661	91,5	0,658	91,3	0,980	1,3	0,555	95,4	0,500	-90,0	0,326	-179,0
19,0	0,667	91,3	0,665	91,2	0,984	1,2	0,493	95,0	0,450	-90,0	0,295	-179,0
20,0	0,672	91,2	0,670	91,1	0,987	1,1	0,440	94,7	0,406	-90,0	0,268	-179,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



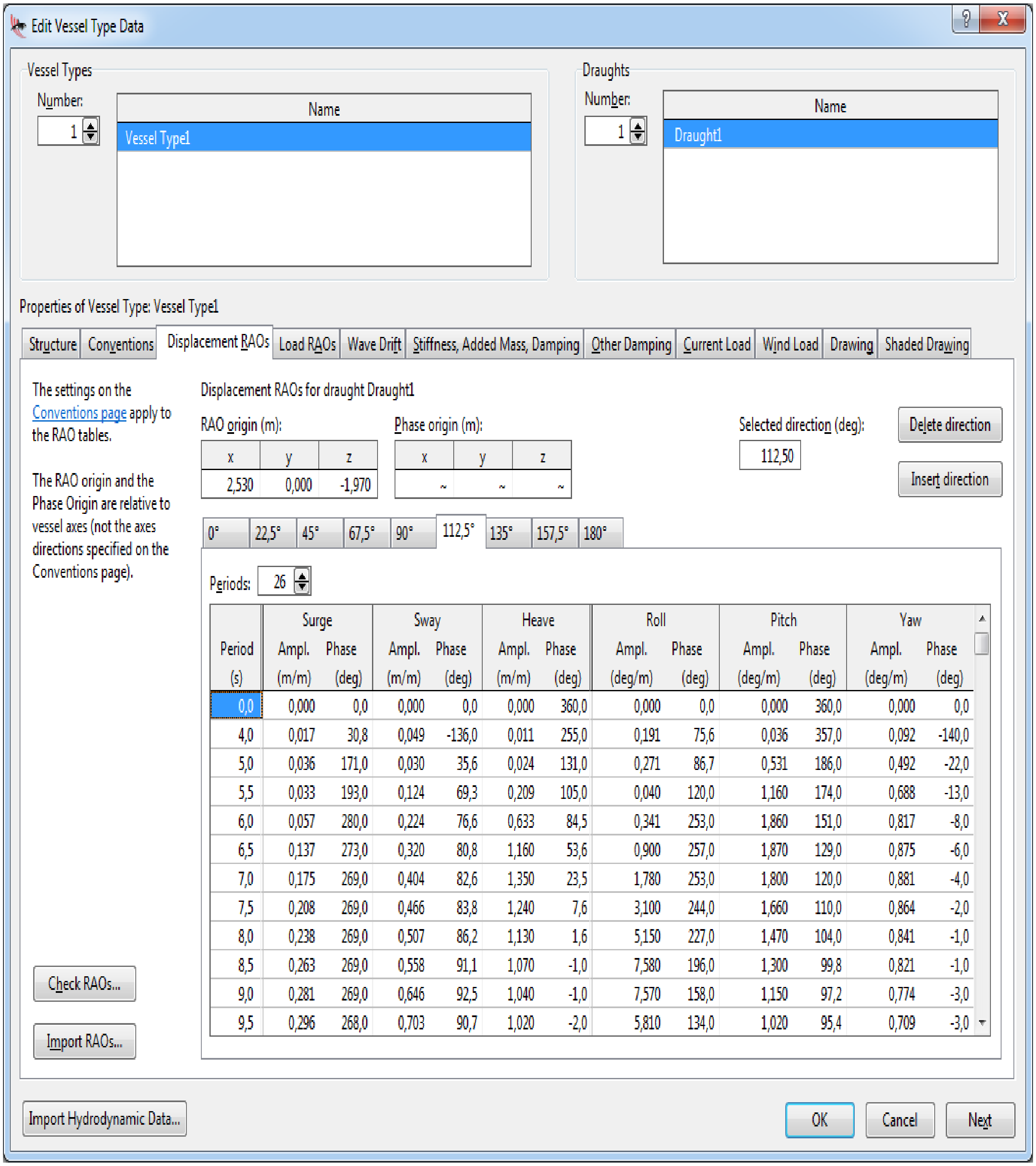
Period (s)	Surge Ampl. (m/m)	Surge Phase (deg)	Sway Ampl. (m/m)	Sway Phase (deg)	Heave Ampl. (m/m)	Heave Phase (deg)	Roll Ampl. (deg/m)	Roll Phase (deg)	Pitch Ampl. (deg/m)	Pitch Phase (deg)	Yaw Ampl. (deg/m)	Yaw Phase (deg)
0,0	0,000	360,0	0,000	0,0	0,000	0,0	0,000	360,0	0,000	360,0	0,000	0,0
4,0	0,0087	361,0	0,221	50,2	0,070	61,3	0,281	229,0	0,090	438,8	0,020	148,0
5,0	0,020	343,0	0,387	71,7	0,284	95,3	0,788	247,0	0,284	438,3	0,020	117,0
5,5	0,035	321,0	0,457	77,0	0,540	94,8	1,180	248,0	0,541	419,9	0,022	105,0
6,0	0,055	276,0	0,518	80,8	0,933	84,2	1,680	250,0	0,969	377,4	0,022	95,4
6,5	0,053	219,0	0,571	83,4	1,490	65,4	2,370	249,0	1,090	317,0	0,024	91,6
7,0	0,034	173,0	0,611	85,2	1,750	35,5	3,350	245,0	0,718	264,0	0,030	85,1
7,5	0,019	144,0	0,638	87,0	1,560	17,0	4,850	237,0	0,391	233,0	0,038	74,0
8,0	0,011	126,0	0,656	89,9	1,370	8,8	7,190	222,0	0,228	217,0	0,049	55,8
8,5	0,0065	115,0	0,700	94,7	1,260	5,0	9,890	192,0	0,143	206,0	0,060	24,1
9,0	0,0039	110,0	0,790	95,3	1,190	3,0	9,450	155,0	0,095	199,0	0,052	-14,0
9,5	0,0023	110,0	0,837	93,0	1,140	1,9	7,030	132,0	0,066	193,0	0,035	-39,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



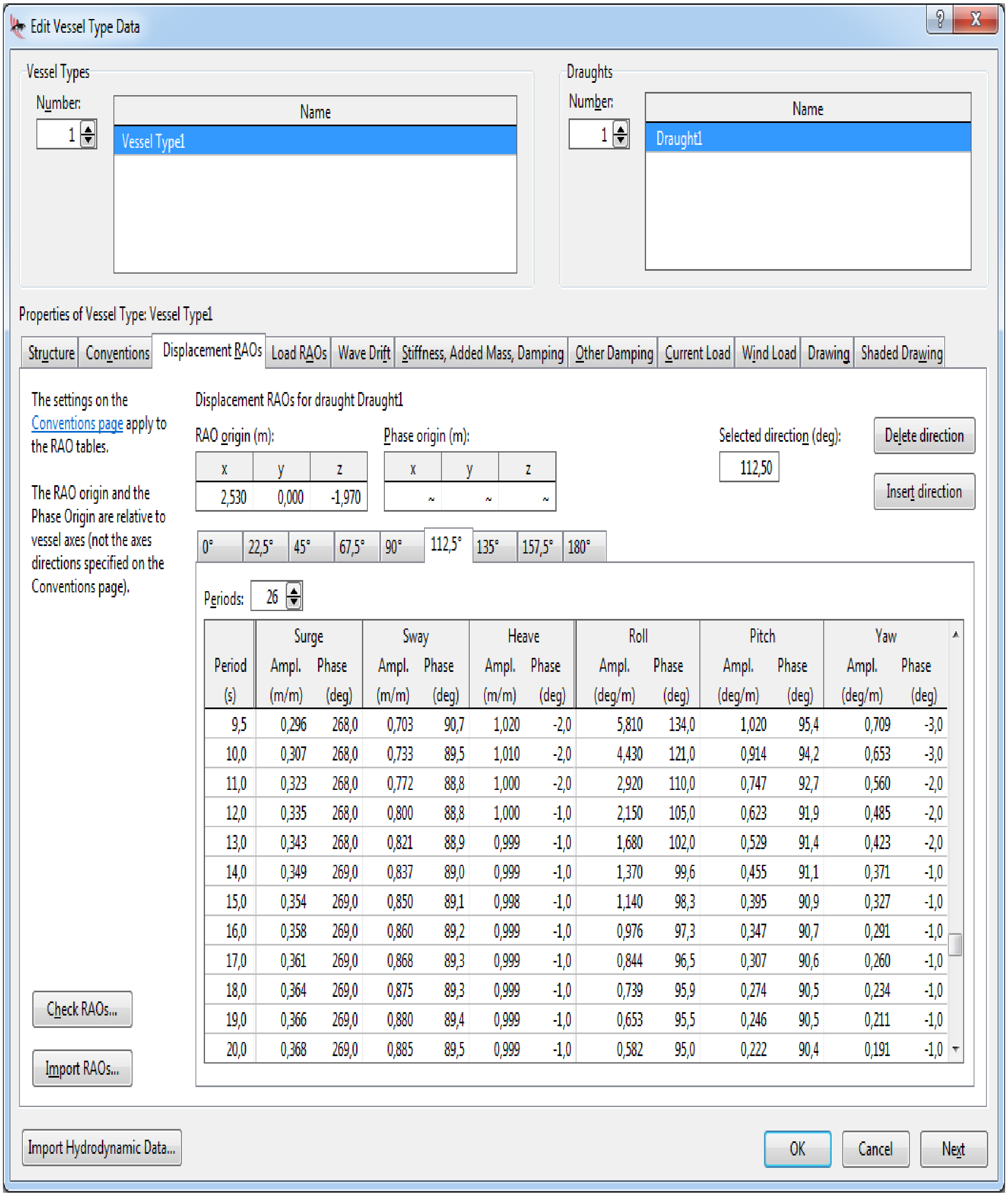
Period	Surge		Sway		Heave		Roll		Pitch		Yaw	
	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase
(s)	(m/m)	(deg)	(m/m)	(deg)	(m/m)	(deg)	(deg/m)	(deg)	(deg/m)	(deg)	(deg/m)	(deg)
9,5	0,0023	110,0	0,837	93,0	1,140	1,9	7,030	132,0	0,066	193,0	0,035	-39,0
10,0	0,0015	119,0	0,857	91,6	1,100	1,3	5,240	120,0	0,048	190,0	0,024	-52,0
11,0	0,00090	148,0	0,880	90,6	1,060	0,59	3,340	109,0	0,027	185,0	0,013	-63,0
12,0	0,00080	166,0	0,897	90,3	1,040	0,29	2,420	104,0	0,016	183,0	0,0085	-69,0
13,0	0,00080	174,0	0,912	90,2	1,030	0,15	1,870	101,0	0,011	182,0	0,0060	-72,0
14,0	0,00070	177,0	0,924	90,1	1,020	0,080	1,510	99,2	0,0074	181,0	0,0045	-74,0
15,0	0,00070	178,0	0,933	90,1	1,010	0,050	1,260	98,0	0,0053	181,0	0,0035	-75,0
16,0	0,00070	179,0	0,941	90,1	1,010	0,030	1,070	97,0	0,0039	180,0	0,0028	-76,0
17,0	0,00060	179,0	0,948	90,0	1,010	0,020	0,922	96,3	0,0029	180,0	0,0023	-77,0
18,0	0,00060	180,0	0,954	90,0	1,010	0,010	0,805	95,8	0,0023	180,0	0,0019	-78,0
19,0	0,00060	180,0	0,958	90,0	1,010	0,010	0,711	95,3	0,0018	180,0	0,0016	-78,0
20,0	0,00050	180,0	0,963	90,0	1,000	0,010	0,633	94,9	0,0014	180,0	0,0014	-79,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



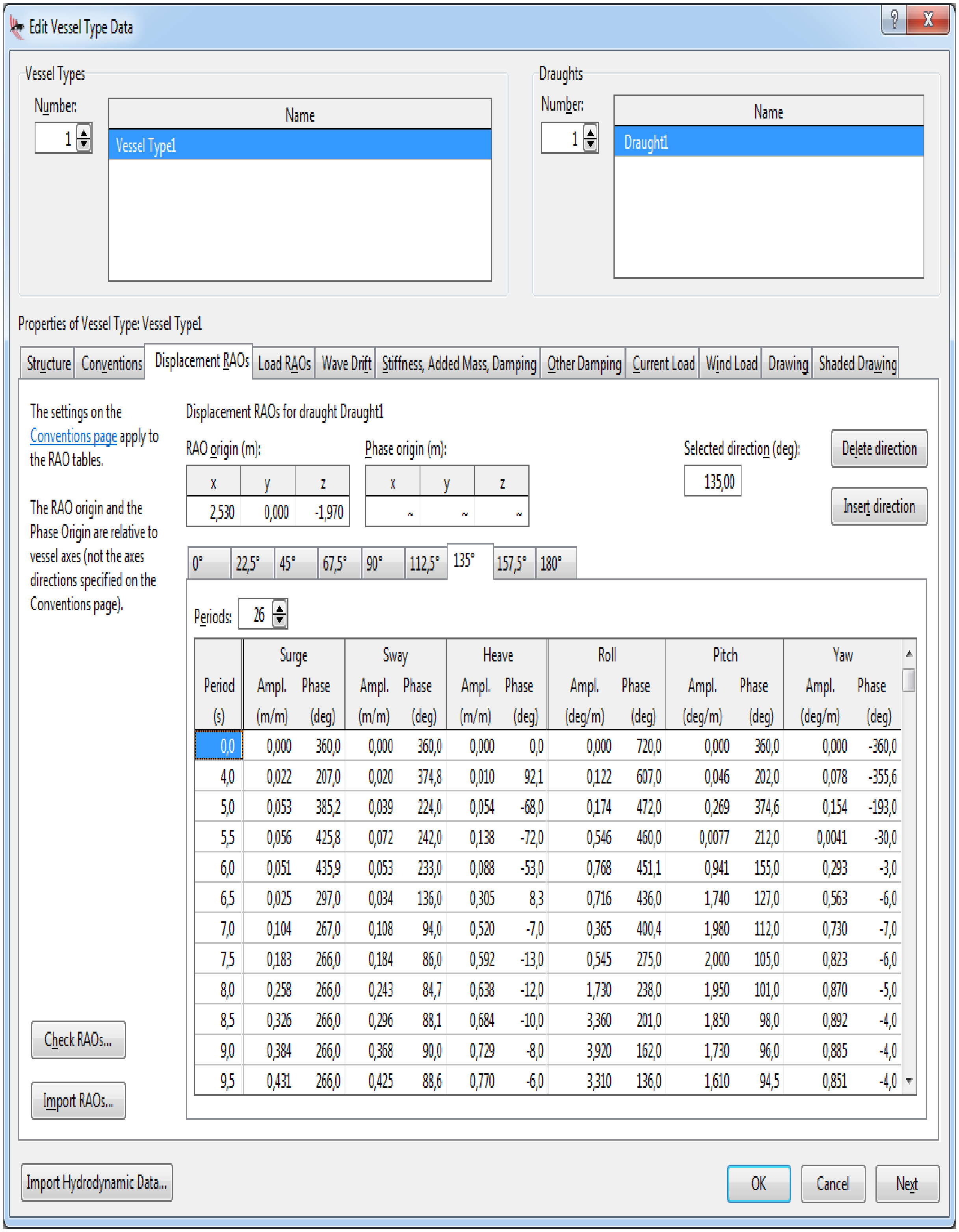
Period (s)	Surge Ampl. (m/m)	Surge Phase (deg)	Sway Ampl. (m/m)	Sway Phase (deg)	Heave Ampl. (m/m)	Heave Phase (deg)	Roll Ampl. (deg/m)	Roll Phase (deg)	Pitch Ampl. (deg/m)	Pitch Phase (deg)	Yaw Ampl. (deg/m)	Yaw Phase (deg)
0,0	0,000	0,0	0,000	0,0	0,000	360,0	0,000	0,0	0,000	360,0	0,000	0,0
4,0	0,017	30,8	0,049	-136,0	0,011	255,0	0,191	75,6	0,036	357,0	0,092	-140,0
5,0	0,036	171,0	0,030	35,6	0,024	131,0	0,271	86,7	0,531	186,0	0,492	-22,0
5,5	0,033	193,0	0,124	69,3	0,209	105,0	0,040	120,0	1,160	174,0	0,688	-13,0
6,0	0,057	280,0	0,224	76,6	0,633	84,5	0,341	253,0	1,860	151,0	0,817	-8,0
6,5	0,137	273,0	0,320	80,8	1,160	53,6	0,900	257,0	1,870	129,0	0,875	-6,0
7,0	0,175	269,0	0,404	82,6	1,350	23,5	1,780	253,0	1,800	120,0	0,881	-4,0
7,5	0,208	269,0	0,466	83,8	1,240	7,6	3,100	244,0	1,660	110,0	0,864	-2,0
8,0	0,238	269,0	0,507	86,2	1,130	1,6	5,150	227,0	1,470	104,0	0,841	-1,0
8,5	0,263	269,0	0,558	91,1	1,070	-1,0	7,580	196,0	1,300	99,8	0,821	-1,0
9,0	0,281	269,0	0,646	92,5	1,040	-1,0	7,570	158,0	1,150	97,2	0,774	-3,0
9,5	0,296	268,0	0,703	90,7	1,020	-2,0	5,810	134,0	1,020	95,4	0,709	-3,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



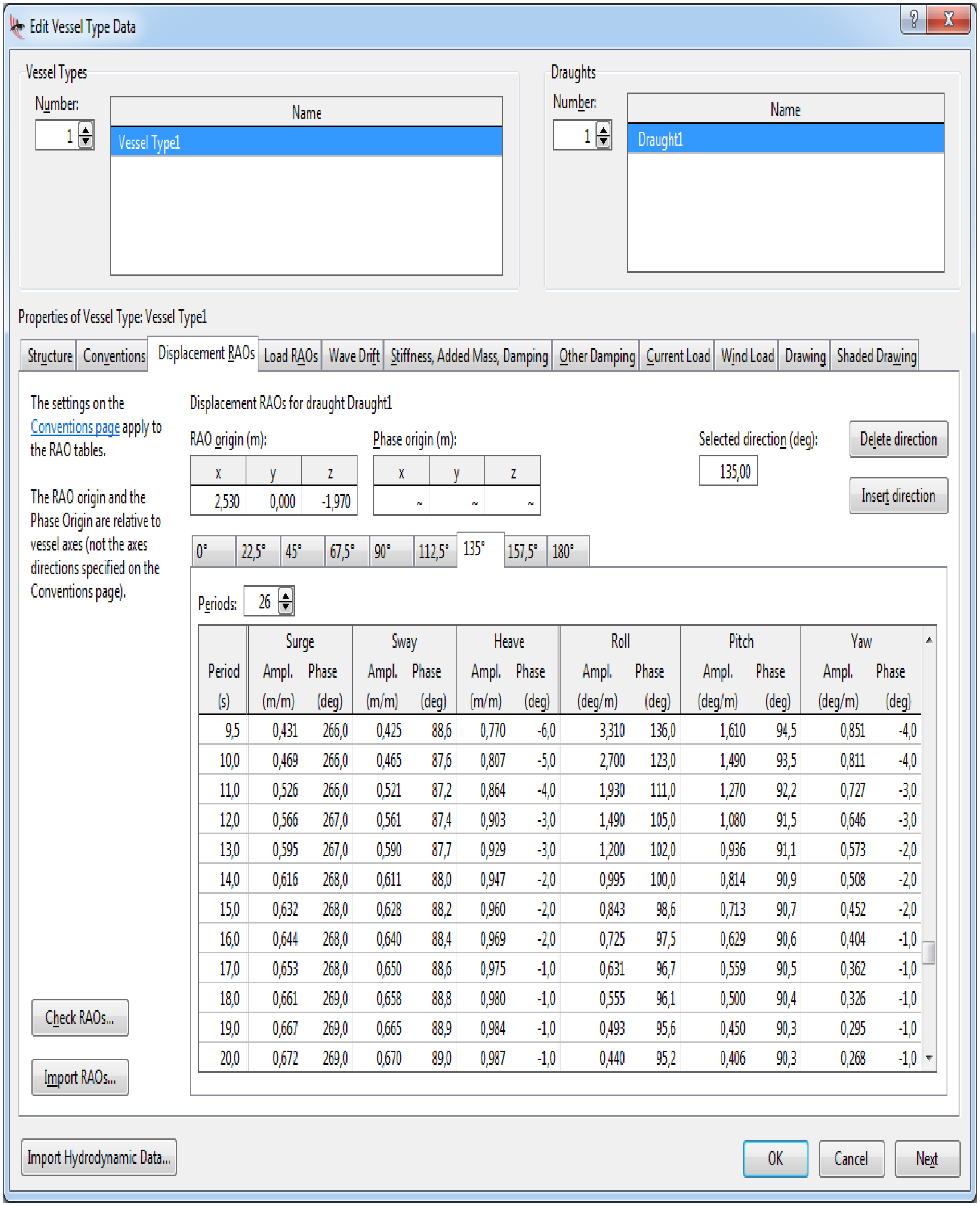
Period	Surge		Sway		Heave		Roll		Pitch		Yaw	
	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase
(s)	(m/m)	(deg)	(m/m)	(deg)	(m/m)	(deg)	(deg/m)	(deg)	(deg/m)	(deg)	(deg/m)	(deg)
9,5	0,296	268,0	0,703	90,7	1,020	-2,0	5,810	134,0	1,020	95,4	0,709	-3,0
10,0	0,307	268,0	0,733	89,5	1,010	-2,0	4,430	121,0	0,914	94,2	0,653	-3,0
11,0	0,323	268,0	0,772	88,8	1,000	-2,0	2,920	110,0	0,747	92,7	0,560	-2,0
12,0	0,335	268,0	0,800	88,8	1,000	-1,0	2,150	105,0	0,623	91,9	0,485	-2,0
13,0	0,343	268,0	0,821	88,9	0,999	-1,0	1,680	102,0	0,529	91,4	0,423	-2,0
14,0	0,349	269,0	0,837	89,0	0,999	-1,0	1,370	99,6	0,455	91,1	0,371	-1,0
15,0	0,354	269,0	0,850	89,1	0,998	-1,0	1,140	98,3	0,395	90,9	0,327	-1,0
16,0	0,358	269,0	0,860	89,2	0,999	-1,0	0,976	97,3	0,347	90,7	0,291	-1,0
17,0	0,361	269,0	0,868	89,3	0,999	-1,0	0,844	96,5	0,307	90,6	0,260	-1,0
18,0	0,364	269,0	0,875	89,3	0,999	-1,0	0,739	95,9	0,274	90,5	0,234	-1,0
19,0	0,366	269,0	0,880	89,4	0,999	-1,0	0,653	95,5	0,246	90,5	0,211	-1,0
20,0	0,368	269,0	0,885	89,5	0,999	-1,0	0,582	95,0	0,222	90,4	0,191	-1,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



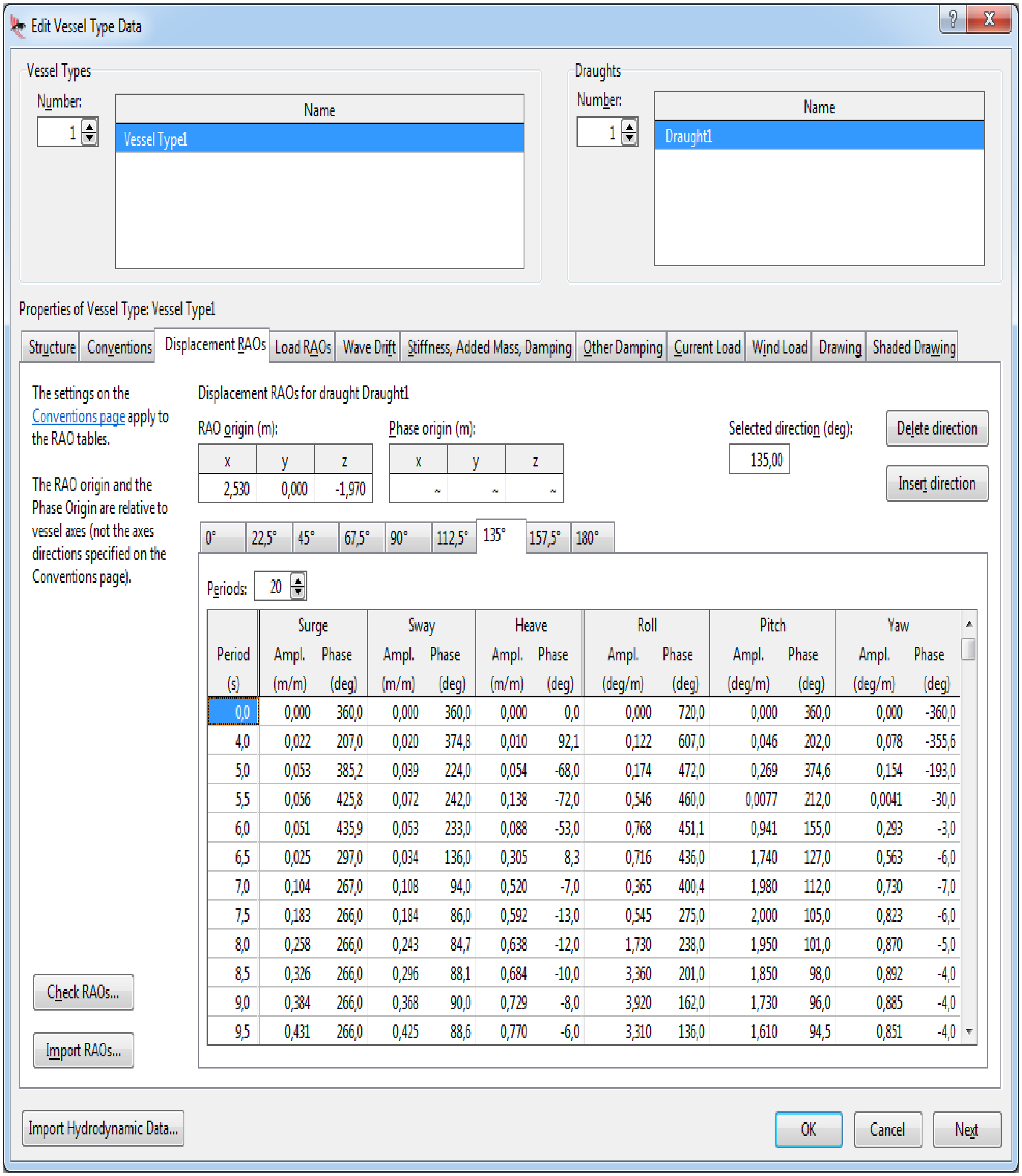
Period (s)	Surge Ampl. (m/m)	Surge Phase (deg)	Sway Ampl. (m/m)	Sway Phase (deg)	Heave Ampl. (m/m)	Heave Phase (deg)	Roll Ampl. (deg/m)	Roll Phase (deg)	Pitch Ampl. (deg/m)	Pitch Phase (deg)	Yaw Ampl. (deg/m)	Yaw Phase (deg)
0,0	0,000	360,0	0,000	360,0	0,000	0,0	0,000	720,0	0,000	360,0	0,000	-360,0
4,0	0,022	207,0	0,020	374,8	0,010	92,1	0,122	607,0	0,046	202,0	0,078	-355,6
5,0	0,053	385,2	0,039	224,0	0,054	-68,0	0,174	472,0	0,269	374,6	0,154	-193,0
5,5	0,056	425,8	0,072	242,0	0,138	-72,0	0,546	460,0	0,0077	212,0	0,0041	-30,0
6,0	0,051	435,9	0,053	233,0	0,088	-53,0	0,768	451,1	0,941	155,0	0,293	-3,0
6,5	0,025	297,0	0,034	136,0	0,305	8,3	0,716	436,0	1,740	127,0	0,563	-6,0
7,0	0,104	267,0	0,108	94,0	0,520	-7,0	0,365	400,4	1,980	112,0	0,730	-7,0
7,5	0,183	266,0	0,184	86,0	0,592	-13,0	0,545	275,0	2,000	105,0	0,823	-6,0
8,0	0,258	266,0	0,243	84,7	0,638	-12,0	1,730	238,0	1,950	101,0	0,870	-5,0
8,5	0,326	266,0	0,296	88,1	0,684	-10,0	3,360	201,0	1,850	98,0	0,892	-4,0
9,0	0,384	266,0	0,368	90,0	0,729	-8,0	3,920	162,0	1,730	96,0	0,885	-4,0
9,5	0,431	266,0	0,425	88,6	0,770	-6,0	3,310	136,0	1,610	94,5	0,851	-4,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



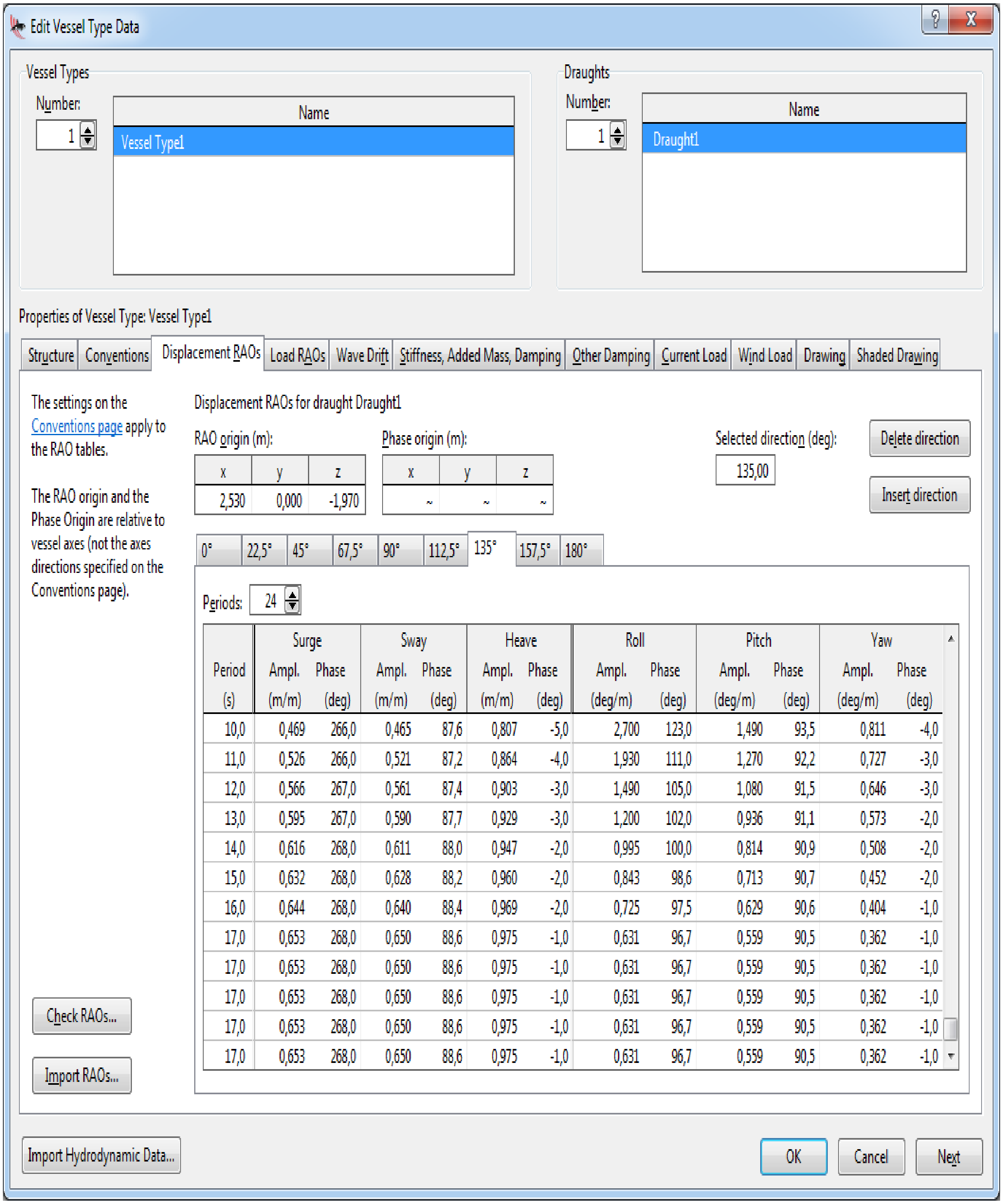
	Surge		Sway		Heave		Roll		Pitch		Yaw	
Period (s)	Ampl. (m/m)	Phase (deg)	Ampl. (m/m)	Phase (deg)	Ampl. (m/m)	Phase (deg)	Ampl. (deg/m)	Phase (deg)	Ampl. (deg/m)	Phase (deg)	Ampl. (deg/m)	Phase (deg)
9,5	0,431	266,0	0,425	88,6	0,770	-6,0	3,310	136,0	1,610	94,5	0,851	-4,0
10,0	0,469	266,0	0,465	87,6	0,807	-5,0	2,700	123,0	1,490	93,5	0,811	-4,0
11,0	0,526	266,0	0,521	87,2	0,864	-4,0	1,930	111,0	1,270	92,2	0,727	-3,0
12,0	0,566	267,0	0,561	87,4	0,903	-3,0	1,490	105,0	1,080	91,5	0,646	-3,0
13,0	0,595	267,0	0,590	87,7	0,929	-3,0	1,200	102,0	0,936	91,1	0,573	-2,0
14,0	0,616	268,0	0,611	88,0	0,947	-2,0	0,995	100,0	0,814	90,9	0,508	-2,0
15,0	0,632	268,0	0,628	88,2	0,960	-2,0	0,843	98,6	0,713	90,7	0,452	-2,0
16,0	0,644	268,0	0,640	88,4	0,969	-2,0	0,725	97,5	0,629	90,6	0,404	-1,0
17,0	0,653	268,0	0,650	88,6	0,975	-1,0	0,631	96,7	0,559	90,5	0,362	-1,0
18,0	0,661	269,0	0,658	88,8	0,980	-1,0	0,555	96,1	0,500	90,4	0,326	-1,0
19,0	0,667	269,0	0,665	88,9	0,984	-1,0	0,493	95,6	0,450	90,3	0,295	-1,0
20,0	0,672	269,0	0,670	89,0	0,987	-1,0	0,440	95,2	0,406	90,3	0,268	-1,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



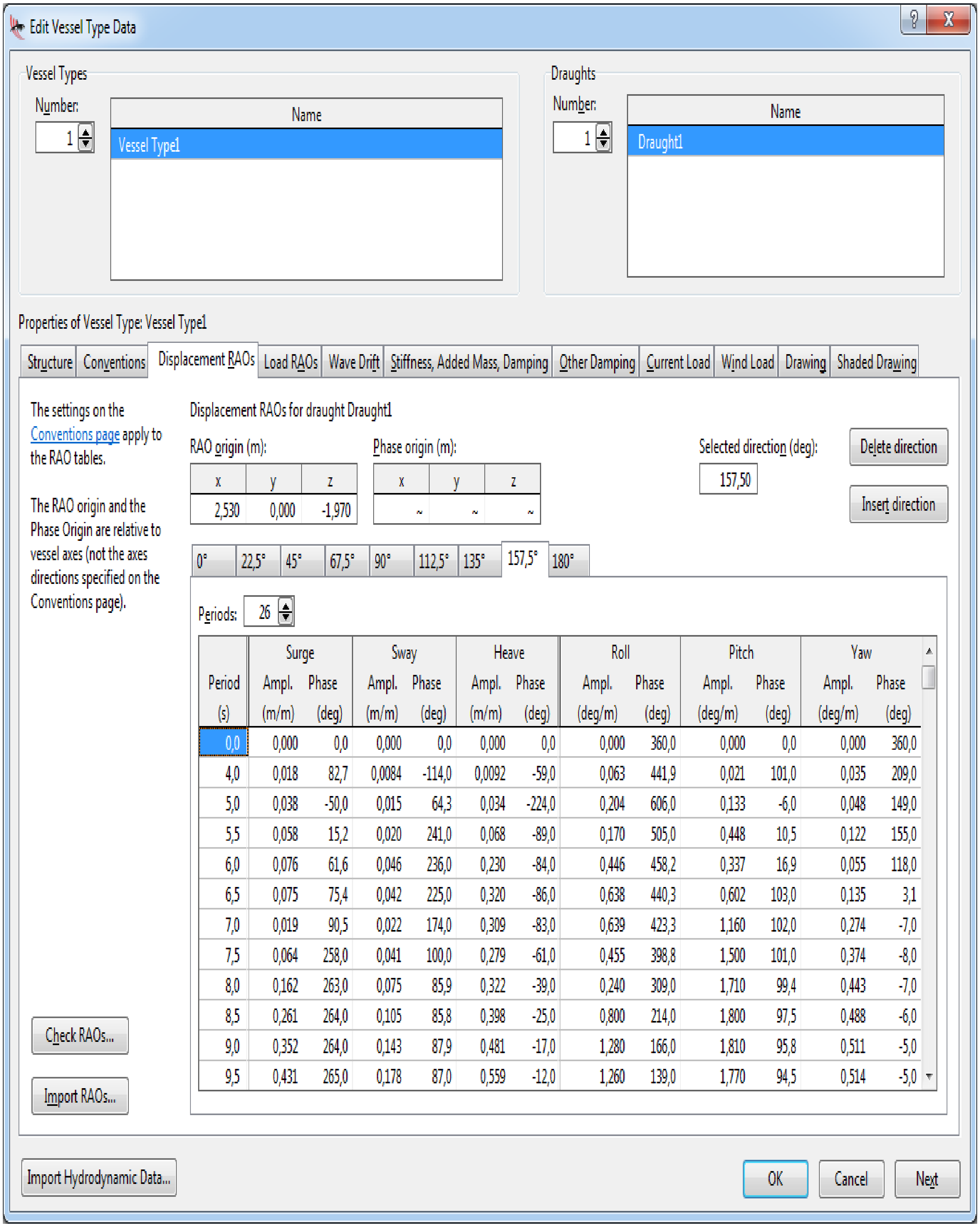
Period (s)	Surge Ampl. (m/m)	Surge Phase (deg)	Sway Ampl. (m/m)	Sway Phase (deg)	Heave Ampl. (m/m)	Heave Phase (deg)	Roll Ampl. (deg/m)	Roll Phase (deg)	Pitch Ampl. (deg/m)	Pitch Phase (deg)	Yaw Ampl. (deg/m)	Yaw Phase (deg)
0,0	0,000	360,0	0,000	360,0	0,000	0,0	0,000	720,0	0,000	360,0	0,000	-360,0
4,0	0,022	207,0	0,020	374,8	0,010	92,1	0,122	607,0	0,046	202,0	0,078	-355,6
5,0	0,053	385,2	0,039	224,0	0,054	-68,0	0,174	472,0	0,269	374,6	0,154	-193,0
5,5	0,056	425,8	0,072	242,0	0,138	-72,0	0,546	460,0	0,0077	212,0	0,0041	-30,0
6,0	0,051	435,9	0,053	233,0	0,088	-53,0	0,768	451,1	0,941	155,0	0,293	-3,0
6,5	0,025	297,0	0,034	136,0	0,305	8,3	0,716	436,0	1,740	127,0	0,563	-6,0
7,0	0,104	267,0	0,108	94,0	0,520	-7,0	0,365	400,4	1,980	112,0	0,730	-7,0
7,5	0,183	266,0	0,184	86,0	0,592	-13,0	0,545	275,0	2,000	105,0	0,823	-6,0
8,0	0,258	266,0	0,243	84,7	0,638	-12,0	1,730	238,0	1,950	101,0	0,870	-5,0
8,5	0,326	266,0	0,296	88,1	0,684	-10,0	3,360	201,0	1,850	98,0	0,892	-4,0
9,0	0,384	266,0	0,368	90,0	0,729	-8,0	3,920	162,0	1,730	96,0	0,885	-4,0
9,5	0,431	266,0	0,425	88,6	0,770	-6,0	3,310	136,0	1,610	94,5	0,851	-4,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



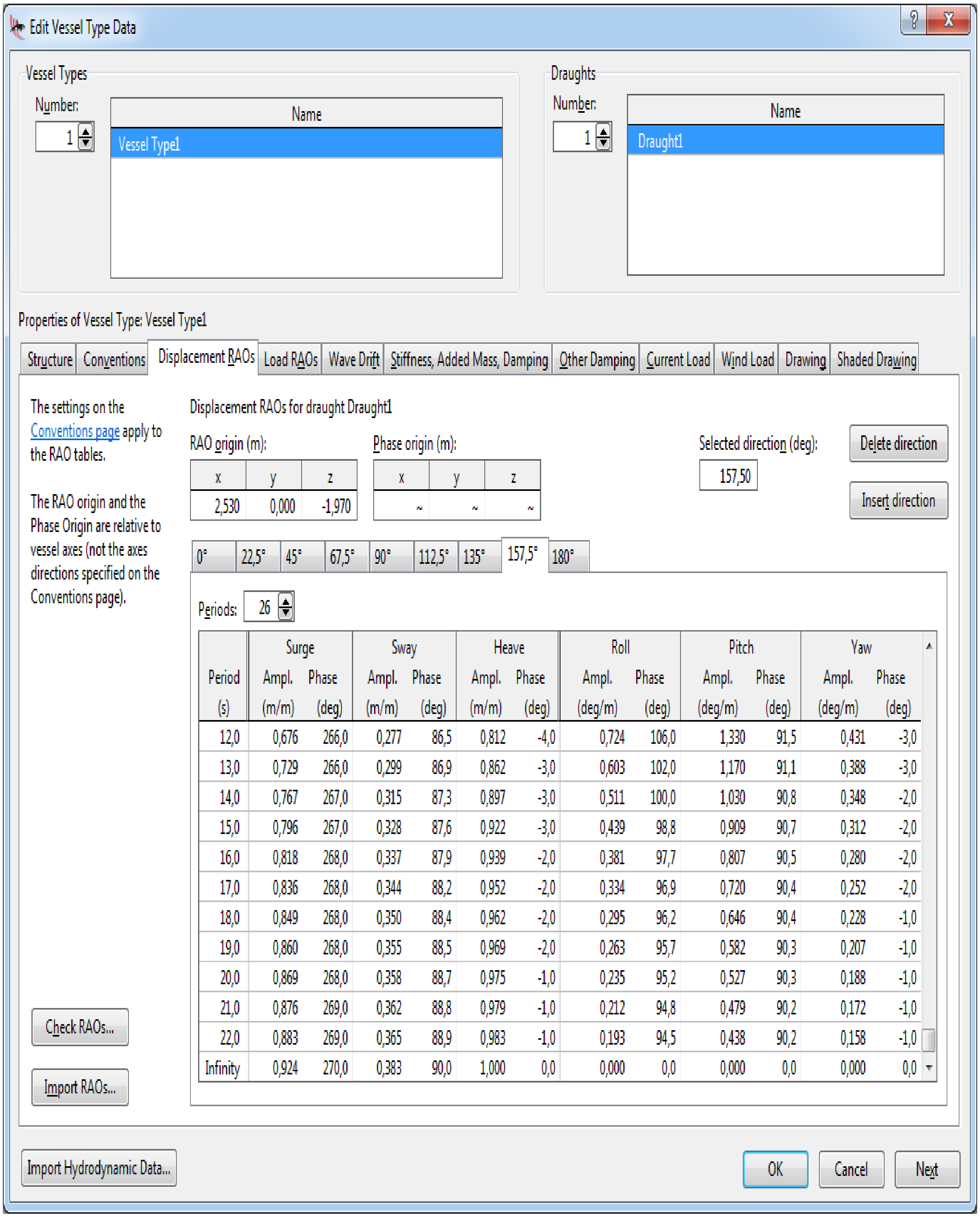
Period (s)	Surge Ampl. (m/m)	Surge Phase (deg)	Sway Ampl. (m/m)	Sway Phase (deg)	Heave Ampl. (m/m)	Heave Phase (deg)	Roll Ampl. (deg/m)	Roll Phase (deg)	Pitch Ampl. (deg/m)	Pitch Phase (deg)	Yaw Ampl. (deg/m)	Yaw Phase (deg)
10,0	0,469	266,0	0,465	87,6	0,807	-5,0	2,700	123,0	1,490	93,5	0,811	-4,0
11,0	0,526	266,0	0,521	87,2	0,864	-4,0	1,930	111,0	1,270	92,2	0,727	-3,0
12,0	0,566	267,0	0,561	87,4	0,903	-3,0	1,490	105,0	1,080	91,5	0,646	-3,0
13,0	0,595	267,0	0,590	87,7	0,929	-3,0	1,200	102,0	0,936	91,1	0,573	-2,0
14,0	0,616	268,0	0,611	88,0	0,947	-2,0	0,995	100,0	0,814	90,9	0,508	-2,0
15,0	0,632	268,0	0,628	88,2	0,960	-2,0	0,843	98,6	0,713	90,7	0,452	-2,0
16,0	0,644	268,0	0,640	88,4	0,969	-2,0	0,725	97,5	0,629	90,6	0,404	-1,0
17,0	0,653	268,0	0,650	88,6	0,975	-1,0	0,631	96,7	0,559	90,5	0,362	-1,0
17,0	0,653	268,0	0,650	88,6	0,975	-1,0	0,631	96,7	0,559	90,5	0,362	-1,0
17,0	0,653	268,0	0,650	88,6	0,975	-1,0	0,631	96,7	0,559	90,5	0,362	-1,0
17,0	0,653	268,0	0,650	88,6	0,975	-1,0	0,631	96,7	0,559	90,5	0,362	-1,0
17,0	0,653	268,0	0,650	88,6	0,975	-1,0	0,631	96,7	0,559	90,5	0,362	-1,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



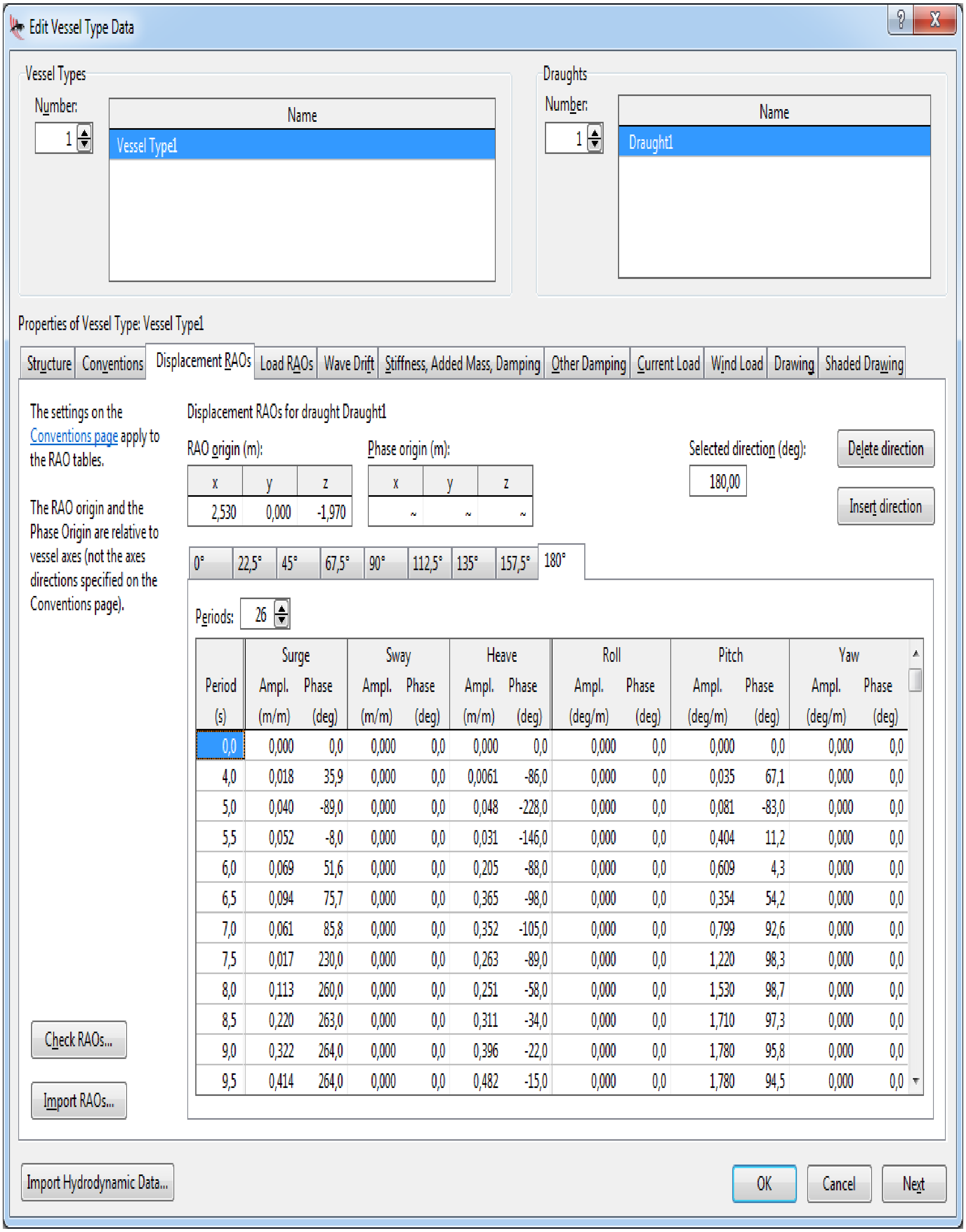
Period	Surge		Sway		Heave		Roll		Pitch		Yaw	
	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase
(s)	(m/m)	(deg)	(m/m)	(deg)	(m/m)	(deg)	(deg/m)	(deg)	(deg/m)	(deg)	(deg/m)	(deg)
0,0	0,000	0,0	0,000	0,0	0,000	0,0	0,000	360,0	0,000	0,0	0,000	360,0
4,0	0,018	82,7	0,0084	-114,0	0,0092	-59,0	0,063	441,9	0,021	101,0	0,035	209,0
5,0	0,038	-50,0	0,015	64,3	0,034	-224,0	0,204	606,0	0,133	-6,0	0,048	149,0
5,5	0,058	15,2	0,020	241,0	0,068	-89,0	0,170	505,0	0,448	10,5	0,122	155,0
6,0	0,076	61,6	0,046	236,0	0,230	-84,0	0,446	458,2	0,337	16,9	0,055	118,0
6,5	0,075	75,4	0,042	225,0	0,320	-86,0	0,638	440,3	0,602	103,0	0,135	3,1
7,0	0,019	90,5	0,022	174,0	0,309	-83,0	0,639	423,3	1,160	102,0	0,274	-7,0
7,5	0,064	258,0	0,041	100,0	0,279	-61,0	0,455	398,8	1,500	101,0	0,374	-8,0
8,0	0,162	263,0	0,075	85,9	0,322	-39,0	0,240	309,0	1,710	99,4	0,443	-7,0
8,5	0,261	264,0	0,105	85,8	0,398	-25,0	0,800	214,0	1,800	97,5	0,488	-6,0
9,0	0,352	264,0	0,143	87,9	0,481	-17,0	1,280	166,0	1,810	95,8	0,511	-5,0
9,5	0,431	265,0	0,178	87,0	0,559	-12,0	1,260	139,0	1,770	94,5	0,514	-5,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



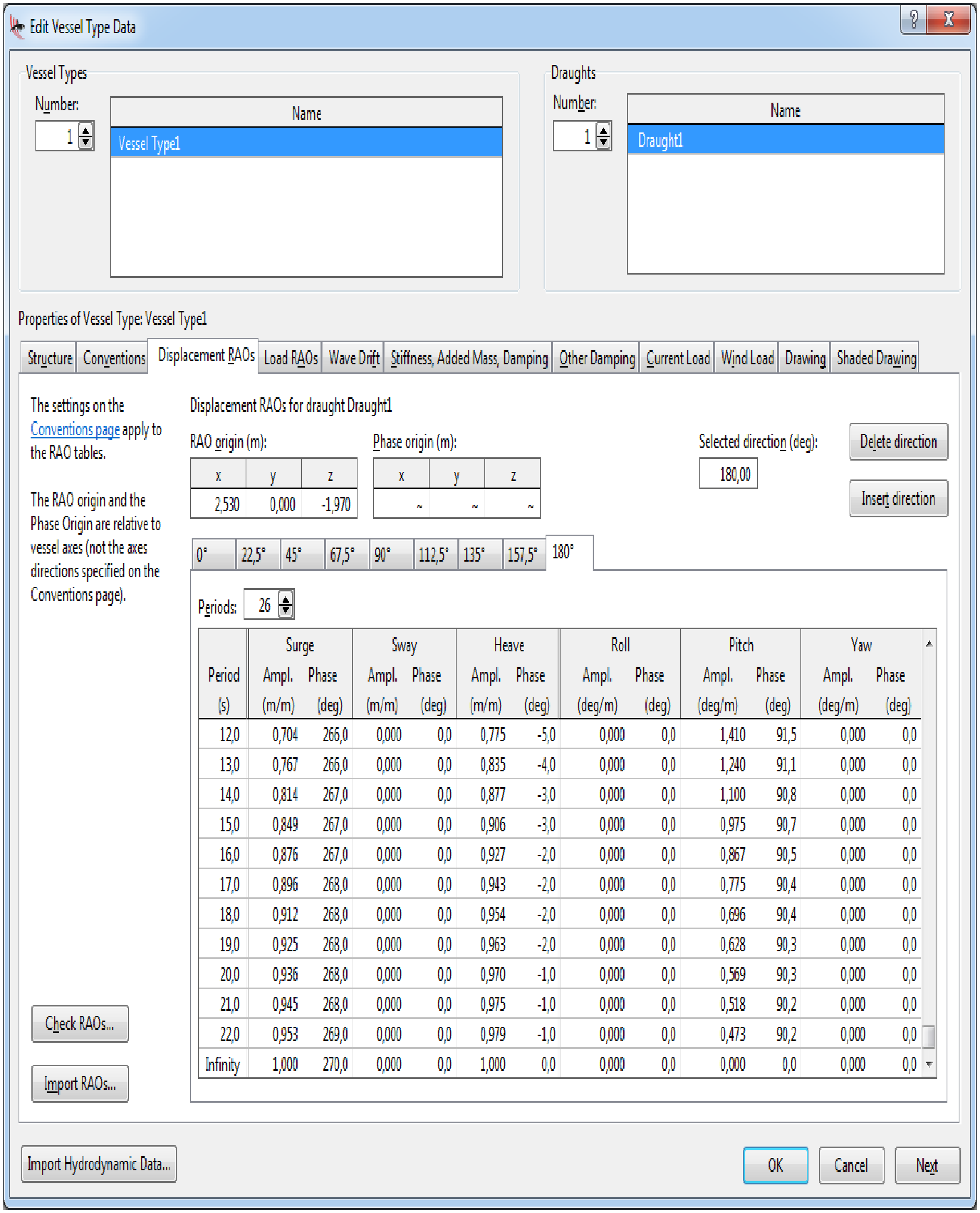
Period (s)	Surge Ampl. (m/m)	Surge Phase (deg)	Sway Ampl. (m/m)	Sway Phase (deg)	Heave Ampl. (m/m)	Heave Phase (deg)	Roll Ampl. (deg/m)	Roll Phase (deg)	Pitch Ampl. (deg/m)	Pitch Phase (deg)	Yaw Ampl. (deg/m)	Yaw Phase (deg)
12,0	0,676	266,0	0,277	86,5	0,812	-4,0	0,724	106,0	1,330	91,5	0,431	-3,0
13,0	0,729	266,0	0,299	86,9	0,862	-3,0	0,603	102,0	1,170	91,1	0,388	-3,0
14,0	0,767	267,0	0,315	87,3	0,897	-3,0	0,511	100,0	1,030	90,8	0,348	-2,0
15,0	0,796	267,0	0,328	87,6	0,922	-3,0	0,439	98,8	0,909	90,7	0,312	-2,0
16,0	0,818	268,0	0,337	87,9	0,939	-2,0	0,381	97,7	0,807	90,5	0,280	-2,0
17,0	0,836	268,0	0,344	88,2	0,952	-2,0	0,334	96,9	0,720	90,4	0,252	-2,0
18,0	0,849	268,0	0,350	88,4	0,962	-2,0	0,295	96,2	0,646	90,4	0,228	-1,0
19,0	0,860	268,0	0,355	88,5	0,969	-2,0	0,263	95,7	0,582	90,3	0,207	-1,0
20,0	0,869	268,0	0,358	88,7	0,975	-1,0	0,235	95,2	0,527	90,3	0,188	-1,0
21,0	0,876	269,0	0,362	88,8	0,979	-1,0	0,212	94,8	0,479	90,2	0,172	-1,0
22,0	0,883	269,0	0,365	88,9	0,983	-1,0	0,193	94,5	0,438	90,2	0,158	-1,0
Infinity	0,924	270,0	0,383	90,0	1,000	0,0	0,000	0,0	0,000	0,0	0,000	0,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



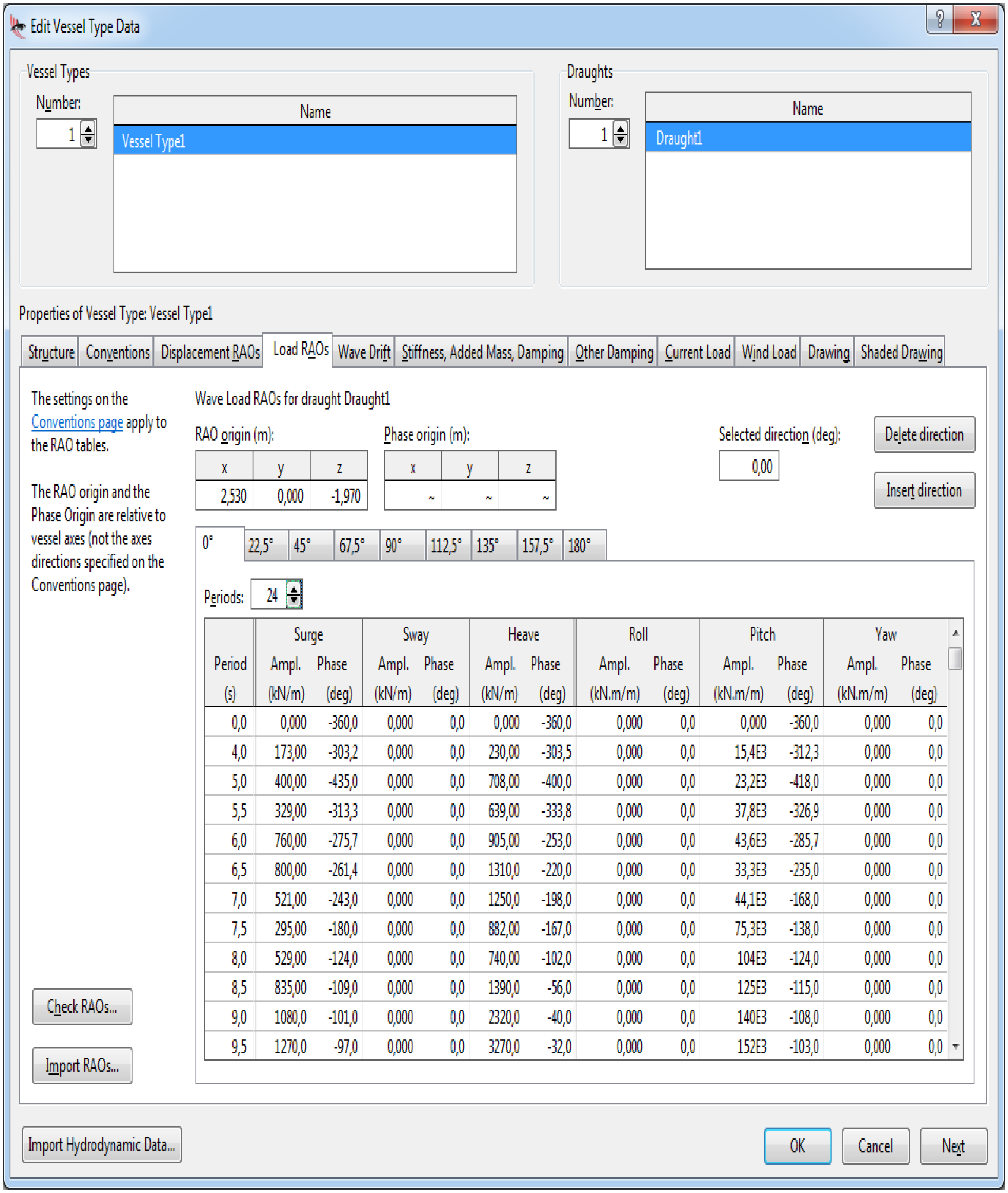
Period	Surge		Sway		Heave		Roll		Pitch		Yaw	
	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase
(s)	(m/m)	(deg)	(m/m)	(deg)	(m/m)	(deg)	(deg/m)	(deg)	(deg/m)	(deg)	(deg/m)	(deg)
0,0	0,000	0,0	0,000	0,0	0,000	0,0	0,000	0,0	0,000	0,0	0,000	0,0
4,0	0,018	35,9	0,000	0,0	0,0061	-86,0	0,000	0,0	0,035	67,1	0,000	0,0
5,0	0,040	-89,0	0,000	0,0	0,048	-228,0	0,000	0,0	0,081	-83,0	0,000	0,0
5,5	0,052	-8,0	0,000	0,0	0,031	-146,0	0,000	0,0	0,404	11,2	0,000	0,0
6,0	0,069	51,6	0,000	0,0	0,205	-88,0	0,000	0,0	0,609	4,3	0,000	0,0
6,5	0,094	75,7	0,000	0,0	0,365	-98,0	0,000	0,0	0,354	54,2	0,000	0,0
7,0	0,061	85,8	0,000	0,0	0,352	-105,0	0,000	0,0	0,799	92,6	0,000	0,0
7,5	0,017	230,0	0,000	0,0	0,263	-89,0	0,000	0,0	1,220	98,3	0,000	0,0
8,0	0,113	260,0	0,000	0,0	0,251	-58,0	0,000	0,0	1,530	98,7	0,000	0,0
8,5	0,220	263,0	0,000	0,0	0,311	-34,0	0,000	0,0	1,710	97,3	0,000	0,0
9,0	0,322	264,0	0,000	0,0	0,396	-22,0	0,000	0,0	1,780	95,8	0,000	0,0
9,5	0,414	264,0	0,000	0,0	0,482	-15,0	0,000	0,0	1,780	94,5	0,000	0,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



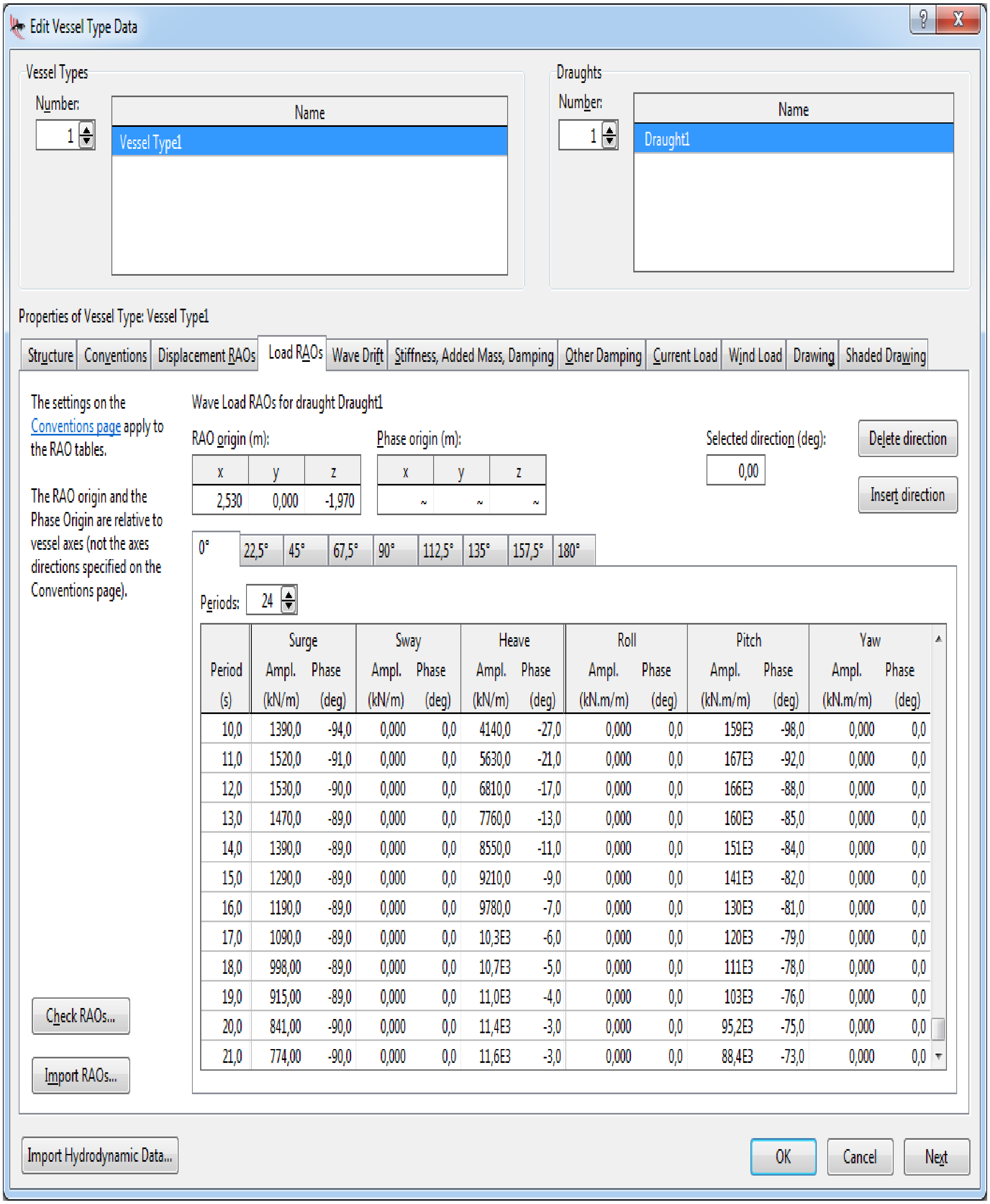
Period (s)	Surge Ampl. (m/m)	Surge Phase (deg)	Sway Ampl. (m/m)	Sway Phase (deg)	Heave Ampl. (m/m)	Heave Phase (deg)	Roll Ampl. (deg/m)	Roll Phase (deg)	Pitch Ampl. (deg/m)	Pitch Phase (deg)	Yaw Ampl. (deg/m)	Yaw Phase (deg)
12,0	0,704	266,0	0,000	0,0	0,775	-5,0	0,000	0,0	1,410	91,5	0,000	0,0
13,0	0,767	266,0	0,000	0,0	0,835	-4,0	0,000	0,0	1,240	91,1	0,000	0,0
14,0	0,814	267,0	0,000	0,0	0,877	-3,0	0,000	0,0	1,100	90,8	0,000	0,0
15,0	0,849	267,0	0,000	0,0	0,906	-3,0	0,000	0,0	0,975	90,7	0,000	0,0
16,0	0,876	267,0	0,000	0,0	0,927	-2,0	0,000	0,0	0,867	90,5	0,000	0,0
17,0	0,896	268,0	0,000	0,0	0,943	-2,0	0,000	0,0	0,775	90,4	0,000	0,0
18,0	0,912	268,0	0,000	0,0	0,954	-2,0	0,000	0,0	0,696	90,4	0,000	0,0
19,0	0,925	268,0	0,000	0,0	0,963	-2,0	0,000	0,0	0,628	90,3	0,000	0,0
20,0	0,936	268,0	0,000	0,0	0,970	-1,0	0,000	0,0	0,569	90,3	0,000	0,0
21,0	0,945	268,0	0,000	0,0	0,975	-1,0	0,000	0,0	0,518	90,2	0,000	0,0
22,0	0,953	269,0	0,000	0,0	0,979	-1,0	0,000	0,0	0,473	90,2	0,000	0,0
Infinity	1,000	270,0	0,000	0,0	1,000	0,0	0,000	0,0	0,000	0,0	0,000	0,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



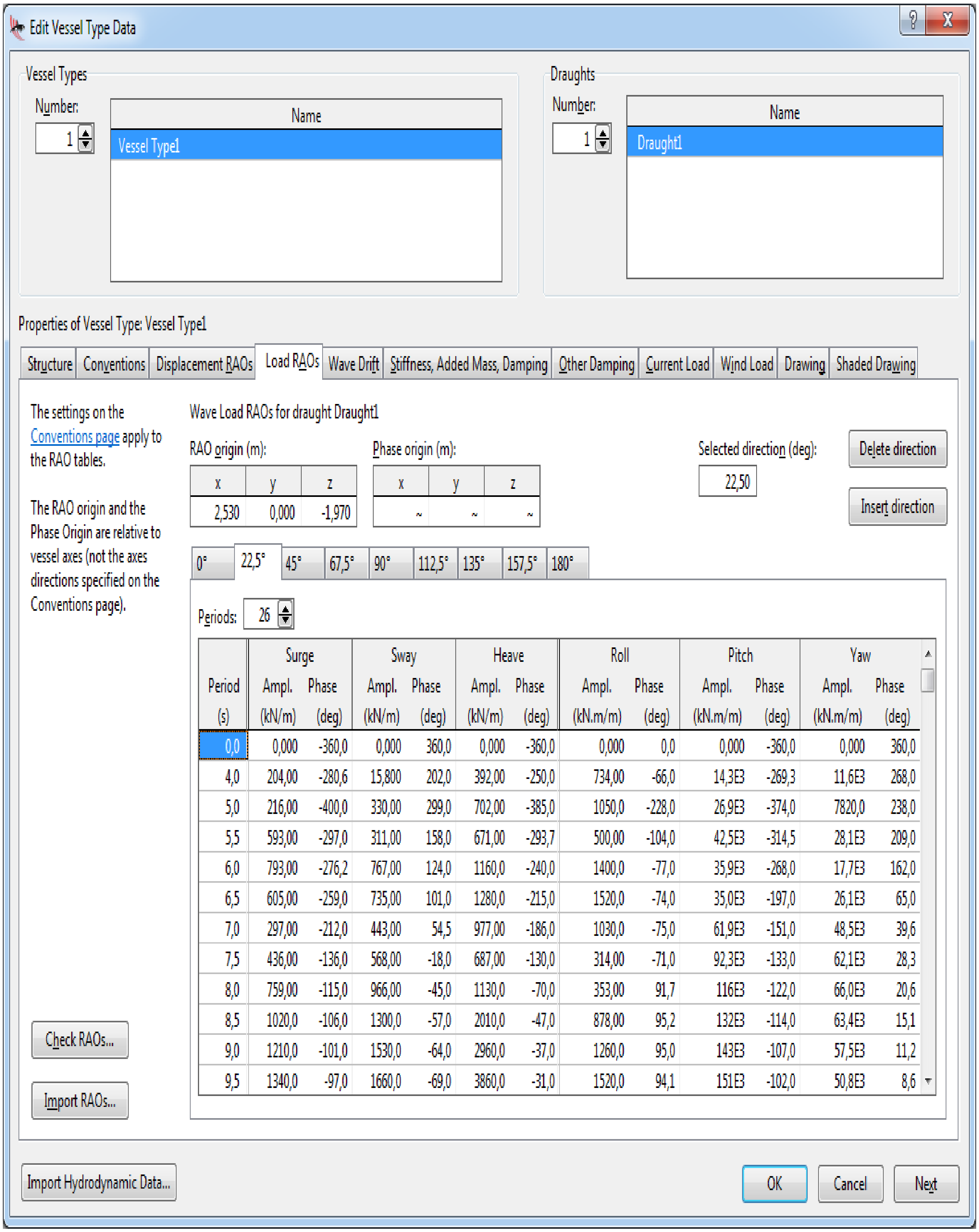
Period	Surge		Sway		Heave		Roll		Pitch		Yaw	
	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase
(s)	(kN/m)	(deg)	(kN/m)	(deg)	(kN/m)	(deg)	(kN.m/m)	(deg)	(kN.m/m)	(deg)	(kN.m/m)	(deg)
0,0	0,000	-360,0	0,000	0,0	0,000	-360,0	0,000	0,0	0,000	-360,0	0,000	0,0
4,0	173,00	-303,2	0,000	0,0	230,00	-303,5	0,000	0,0	15,4E3	-312,3	0,000	0,0
5,0	400,00	-435,0	0,000	0,0	708,00	-400,0	0,000	0,0	23,2E3	-418,0	0,000	0,0
5,5	329,00	-313,3	0,000	0,0	639,00	-333,8	0,000	0,0	37,8E3	-326,9	0,000	0,0
6,0	760,00	-275,7	0,000	0,0	905,00	-253,0	0,000	0,0	43,6E3	-285,7	0,000	0,0
6,5	800,00	-261,4	0,000	0,0	1310,0	-220,0	0,000	0,0	33,3E3	-235,0	0,000	0,0
7,0	521,00	-243,0	0,000	0,0	1250,0	-198,0	0,000	0,0	44,1E3	-168,0	0,000	0,0
7,5	295,00	-180,0	0,000	0,0	882,00	-167,0	0,000	0,0	75,3E3	-138,0	0,000	0,0
8,0	529,00	-124,0	0,000	0,0	740,00	-102,0	0,000	0,0	104E3	-124,0	0,000	0,0
8,5	835,00	-109,0	0,000	0,0	1390,0	-56,0	0,000	0,0	125E3	-115,0	0,000	0,0
9,0	1080,0	-101,0	0,000	0,0	2320,0	-40,0	0,000	0,0	140E3	-108,0	0,000	0,0
9,5	1270,0	-97,0	0,000	0,0	3270,0	-32,0	0,000	0,0	152E3	-103,0	0,000	0,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



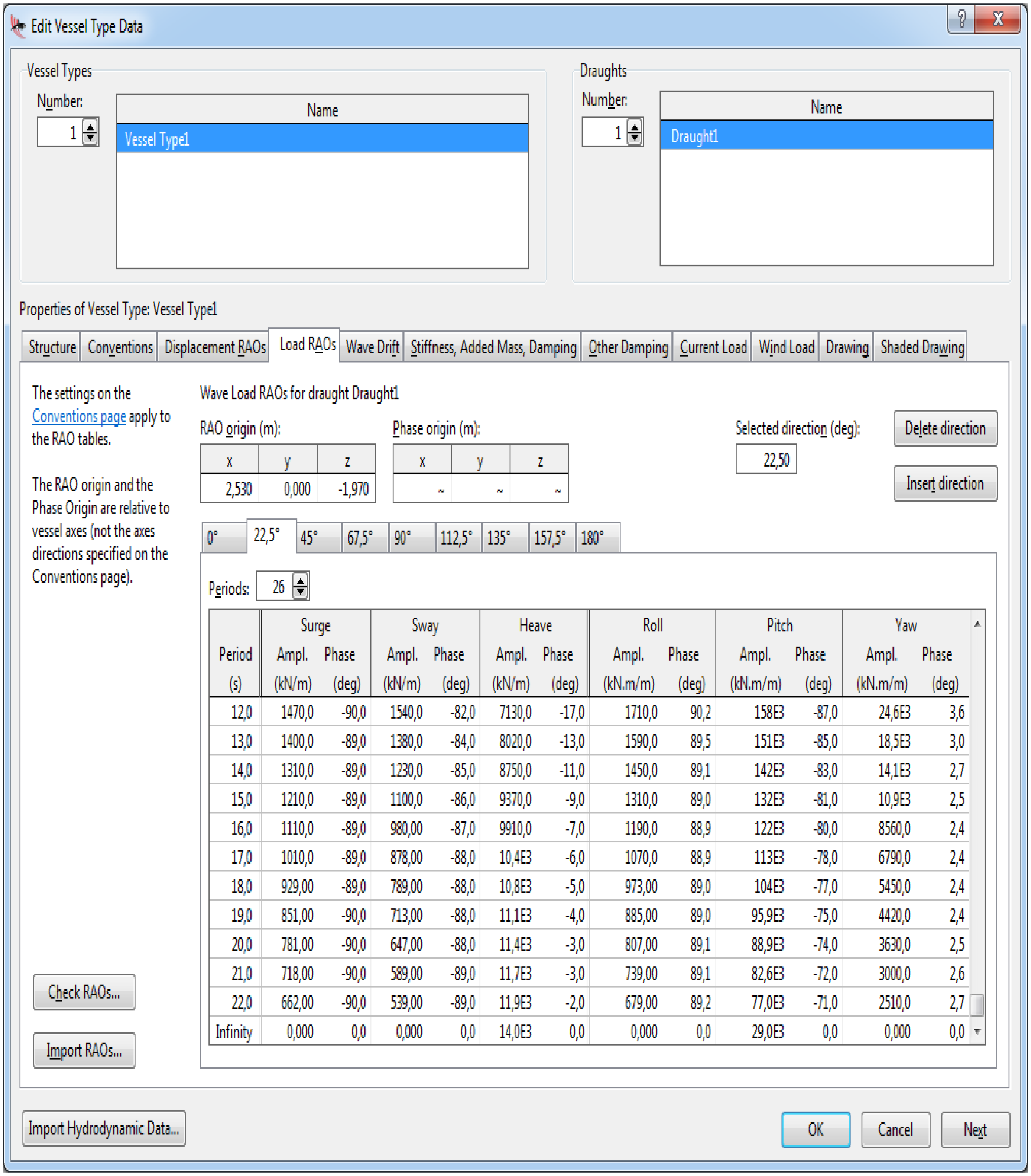
Period (s)	Surge Ampl. (kN/m)	Surge Phase (deg)	Sway Ampl. (kN/m)	Sway Phase (deg)	Heave Ampl. (kN/m)	Heave Phase (deg)	Roll Ampl. (kN.m/m)	Roll Phase (deg)	Pitch Ampl. (kN.m/m)	Pitch Phase (deg)	Yaw Ampl. (kN.m/m)	Yaw Phase (deg)
10,0	1390,0	-94,0	0,000	0,0	4140,0	-27,0	0,000	0,0	159E3	-98,0	0,000	0,0
11,0	1520,0	-91,0	0,000	0,0	5630,0	-21,0	0,000	0,0	167E3	-92,0	0,000	0,0
12,0	1530,0	-90,0	0,000	0,0	6810,0	-17,0	0,000	0,0	166E3	-88,0	0,000	0,0
13,0	1470,0	-89,0	0,000	0,0	7760,0	-13,0	0,000	0,0	160E3	-85,0	0,000	0,0
14,0	1390,0	-89,0	0,000	0,0	8550,0	-11,0	0,000	0,0	151E3	-84,0	0,000	0,0
15,0	1290,0	-89,0	0,000	0,0	9210,0	-9,0	0,000	0,0	141E3	-82,0	0,000	0,0
16,0	1190,0	-89,0	0,000	0,0	9780,0	-7,0	0,000	0,0	130E3	-81,0	0,000	0,0
17,0	1090,0	-89,0	0,000	0,0	10,3E3	-6,0	0,000	0,0	120E3	-79,0	0,000	0,0
18,0	998,00	-89,0	0,000	0,0	10,7E3	-5,0	0,000	0,0	111E3	-78,0	0,000	0,0
19,0	915,00	-89,0	0,000	0,0	11,0E3	-4,0	0,000	0,0	103E3	-76,0	0,000	0,0
20,0	841,00	-90,0	0,000	0,0	11,4E3	-3,0	0,000	0,0	95,2E3	-75,0	0,000	0,0
21,0	774,00	-90,0	0,000	0,0	11,6E3	-3,0	0,000	0,0	88,4E3	-73,0	0,000	0,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



Period (s)	Surge Ampl. (kN/m)	Surge Phase (deg)	Sway Ampl. (kN/m)	Sway Phase (deg)	Heave Ampl. (kN/m)	Heave Phase (deg)	Roll Ampl. (kN.m/m)	Roll Phase (deg)	Pitch Ampl. (kN.m/m)	Pitch Phase (deg)	Yaw Ampl. (kN.m/m)	Yaw Phase (deg)
0,0	0,000	-360,0	0,000	360,0	0,000	-360,0	0,000	0,0	0,000	-360,0	0,000	360,0
4,0	204,00	-280,6	15,800	202,0	392,00	-250,0	734,00	-66,0	14,3E3	-269,3	11,6E3	268,0
5,0	216,00	-400,0	330,00	299,0	702,00	-385,0	1050,0	-228,0	26,9E3	-374,0	7820,0	238,0
5,5	593,00	-297,0	311,00	158,0	671,00	-293,7	500,00	-104,0	42,5E3	-314,5	28,1E3	209,0
6,0	793,00	-276,2	767,00	124,0	1160,0	-240,0	1400,0	-77,0	35,9E3	-268,0	17,7E3	162,0
6,5	605,00	-259,0	735,00	101,0	1280,0	-215,0	1520,0	-74,0	35,0E3	-197,0	26,1E3	65,0
7,0	297,00	-212,0	443,00	54,5	977,00	-186,0	1030,0	-75,0	61,9E3	-151,0	48,5E3	39,6
7,5	436,00	-136,0	568,00	-18,0	687,00	-130,0	314,00	-71,0	92,3E3	-133,0	62,1E3	28,3
8,0	759,00	-115,0	966,00	-45,0	1130,0	-70,0	353,00	91,7	116E3	-122,0	66,0E3	20,6
8,5	1020,0	-106,0	1300,0	-57,0	2010,0	-47,0	878,00	95,2	132E3	-114,0	63,4E3	15,1
9,0	1210,0	-101,0	1530,0	-64,0	2960,0	-37,0	1260,0	95,0	143E3	-107,0	57,5E3	11,2
9,5	1340,0	-97,0	1660,0	-69,0	3860,0	-31,0	1520,0	94,1	151E3	-102,0	50,8E3	8,6

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



Edit Vessel Type Data

Vessel Types — Number: 1 — Name: Vessel Type1

Draughts — Number: 1 — Name: Draught1

Properties of Vessel Type: Vessel Type1

Structure | Conventions | Displacement RAOs | Load RAOs | Wave Drift | Stiffness, Added Mass, Damping | Other Damping | Current Load | Wind Load | Drawing | Shaded Drawing

The settings on the Conventions page apply to the RAO tables.

The RAO origin and the Phase Origin are relative to vessel axes (not the axes directions specified on the Conventions page).

Wave Load RAOs for draught Draught1

RAO origin (m): x 2,530, y 0,000, z -1,970

Phase origin (m): x ~, y ~, z ~

Selected direction (deg): 22,50

Delete direction | Insert direction

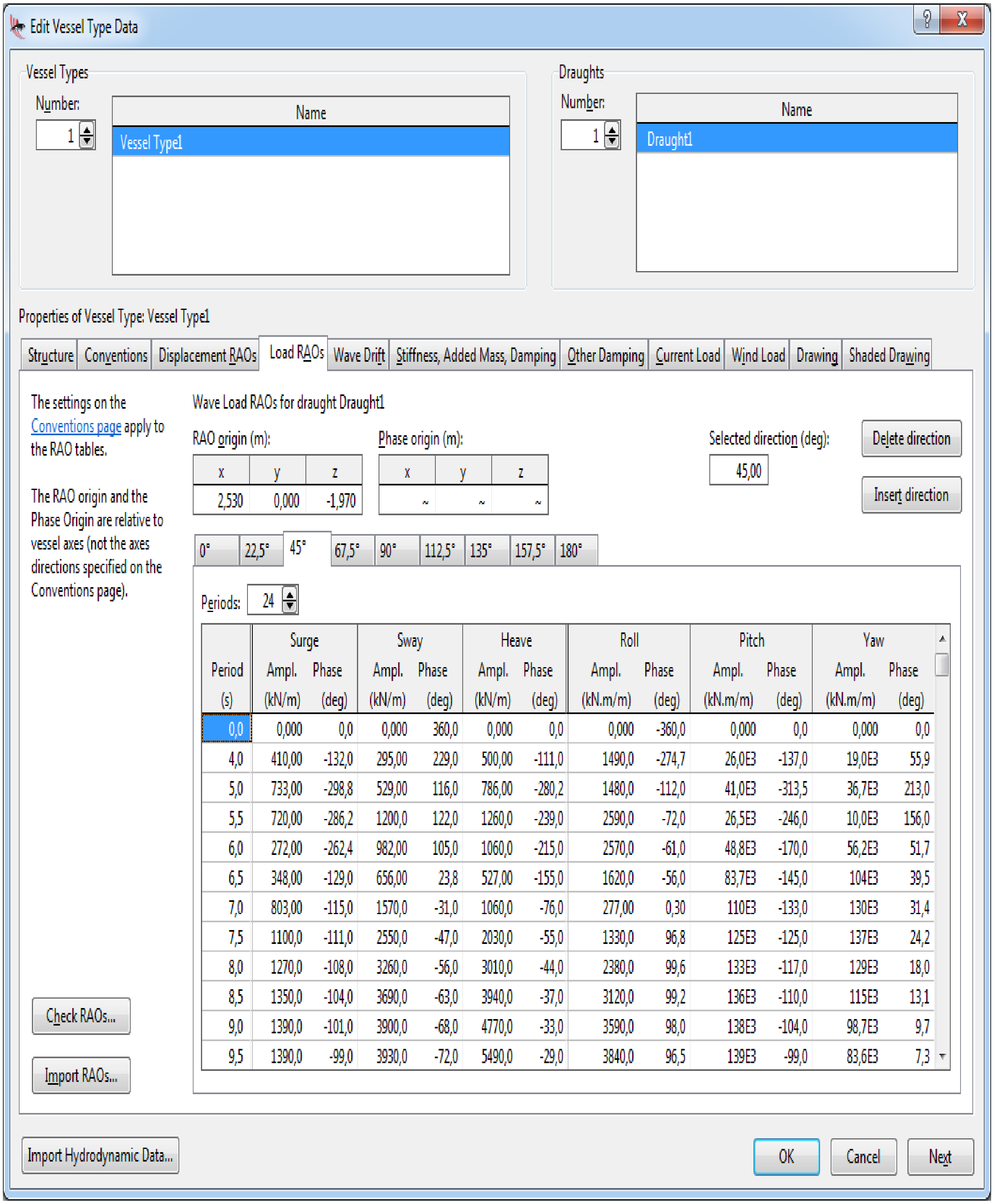
0° | 22,5° | 45° | 67,5° | 90° | 112,5° | 135° | 157,5° | 180°

Periods: 26

Period (s)	Surge Ampl. (kN/m)	Surge Phase (deg)	Sway Ampl. (kN/m)	Sway Phase (deg)	Heave Ampl. (kN/m)	Heave Phase (deg)	Roll Ampl. (kN.m/m)	Roll Phase (deg)	Pitch Ampl. (kN.m/m)	Pitch Phase (deg)	Yaw Ampl. (kN.m/m)	Yaw Phase (deg)
12,0	1470,0	-90,0	1540,0	-82,0	7130,0	-17,0	1710,0	90,2	158E3	-87,0	24,6E3	3,6
13,0	1400,0	-89,0	1380,0	-84,0	8020,0	-13,0	1590,0	89,5	151E3	-85,0	18,5E3	3,0
14,0	1310,0	-89,0	1230,0	-85,0	8750,0	-11,0	1450,0	89,1	142E3	-83,0	14,1E3	2,7
15,0	1210,0	-89,0	1100,0	-86,0	9370,0	-9,0	1310,0	89,0	132E3	-81,0	10,9E3	2,5
16,0	1110,0	-89,0	980,00	-87,0	9910,0	-7,0	1190,0	88,9	122E3	-80,0	8560,0	2,4
17,0	1010,0	-89,0	878,00	-88,0	10,4E3	-6,0	1070,0	88,9	113E3	-78,0	6790,0	2,4
18,0	929,00	-89,0	789,00	-88,0	10,8E3	-5,0	973,00	89,0	104E3	-77,0	5450,0	2,4
19,0	851,00	-90,0	713,00	-88,0	11,1E3	-4,0	885,00	89,0	95,9E3	-75,0	4420,0	2,4
20,0	781,00	-90,0	647,00	-88,0	11,4E3	-3,0	807,00	89,1	88,9E3	-74,0	3630,0	2,5
21,0	718,00	-90,0	589,00	-89,0	11,7E3	-3,0	739,00	89,1	82,6E3	-72,0	3000,0	2,6
22,0	662,00	-90,0	539,00	-89,0	11,9E3	-2,0	679,00	89,2	77,0E3	-71,0	2510,0	2,7
Infinity	0,000	0,0	0,000	0,0	14,0E3	0,0	0,000	0,0	29,0E3	0,0	0,000	0,0

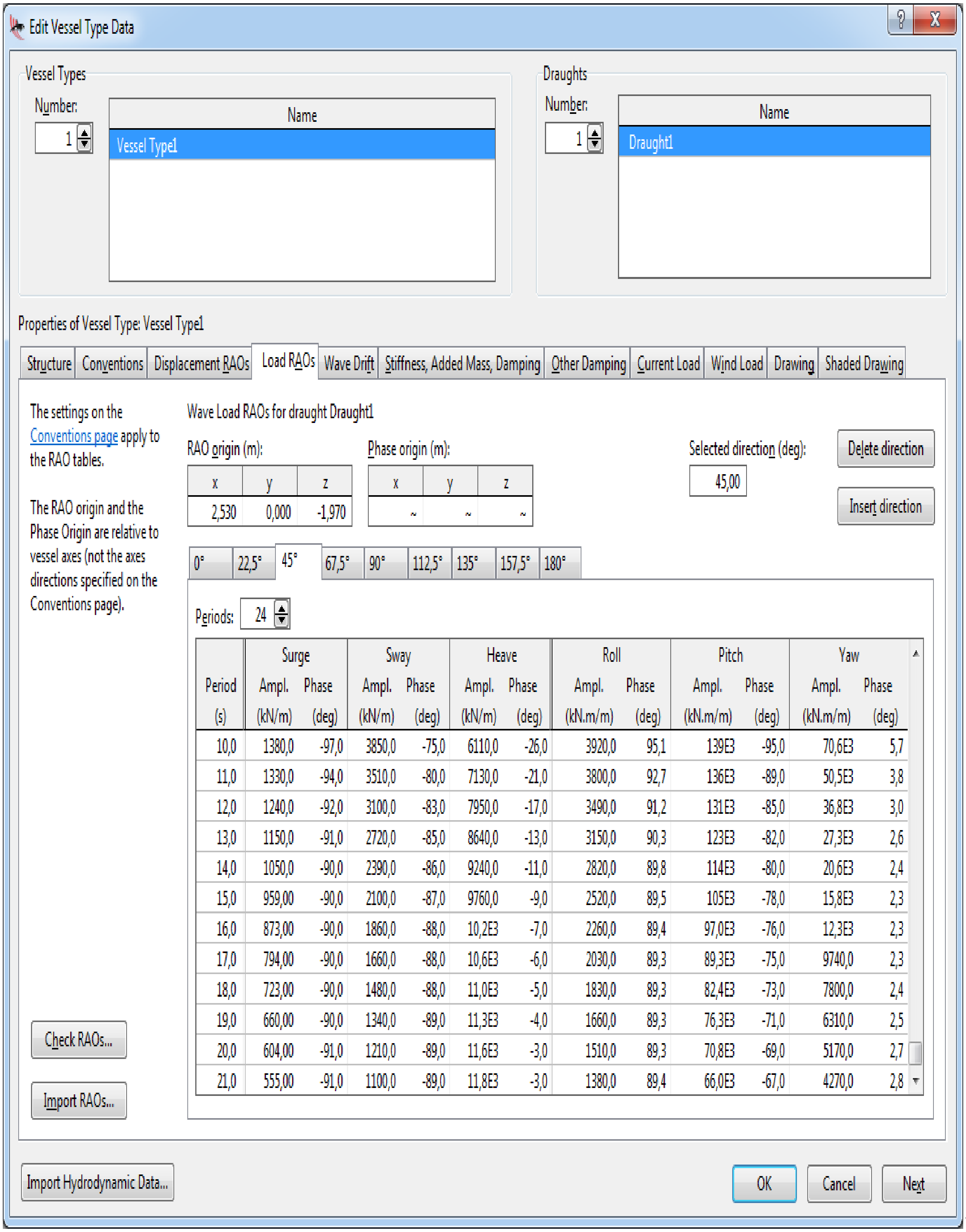
Check RAOs... | Import RAOs... | Import Hydrodynamic Data... | OK | Cancel | Next

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



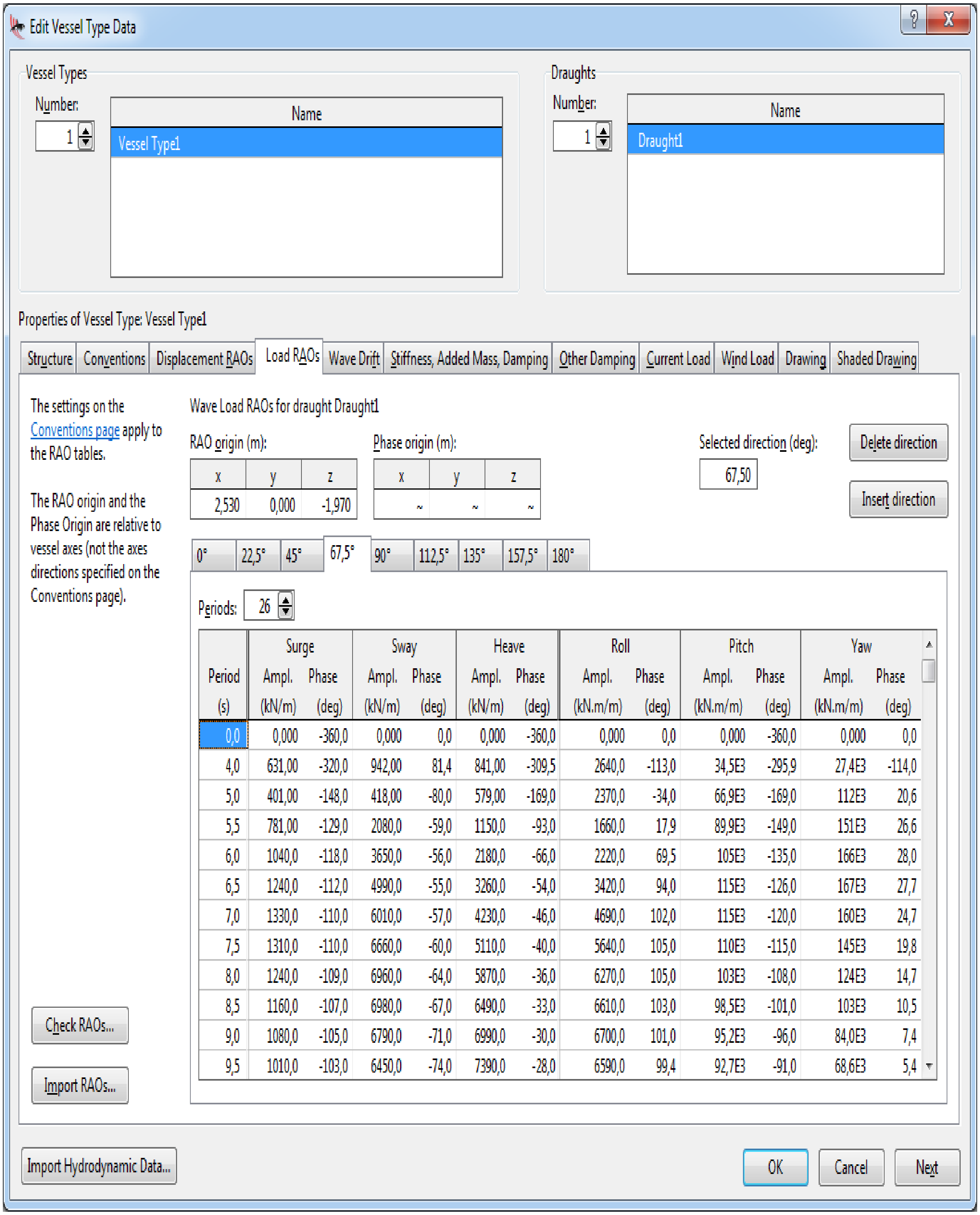
Period	Surge		Sway		Heave		Roll		Pitch		Yaw	
(s)	Ampl. (kN/m)	Phase (deg)	Ampl. (kN/m)	Phase (deg)	Ampl. (kN/m)	Phase (deg)	Ampl. (kN.m/m)	Phase (deg)	Ampl. (kN.m/m)	Phase (deg)	Ampl. (kN.m/m)	Phase (deg)
0,0	0,000	0,0	0,000	360,0	0,000	0,0	0,000	-360,0	0,000	0,0	0,000	0,0
4,0	410,00	-132,0	295,00	229,0	500,00	-111,0	1490,0	-274,7	26,0E3	-137,0	19,0E3	55,9
5,0	733,00	-298,8	529,00	116,0	786,00	-280,2	1480,0	-112,0	41,0E3	-313,5	36,7E3	213,0
5,5	720,00	-286,2	1200,0	122,0	1260,0	-239,0	2590,0	-72,0	26,5E3	-246,0	10,0E3	156,0
6,0	272,00	-262,4	982,00	105,0	1060,0	-215,0	2570,0	-61,0	48,8E3	-170,0	56,2E3	51,7
6,5	348,00	-129,0	656,00	23,8	527,00	-155,0	1620,0	-56,0	83,7E3	-145,0	104E3	39,5
7,0	803,00	-115,0	1570,0	-31,0	1060,0	-76,0	277,00	0,30	110E3	-133,0	130E3	31,4
7,5	1100,0	-111,0	2550,0	-47,0	2030,0	-55,0	1330,0	96,8	125E3	-125,0	137E3	24,2
8,0	1270,0	-108,0	3260,0	-56,0	3010,0	-44,0	2380,0	99,6	133E3	-117,0	129E3	18,0
8,5	1350,0	-104,0	3690,0	-63,0	3940,0	-37,0	3120,0	99,2	136E3	-110,0	115E3	13,1
9,0	1390,0	-101,0	3900,0	-68,0	4770,0	-33,0	3590,0	98,0	138E3	-104,0	98,7E3	9,7
9,5	1390,0	-99,0	3930,0	-72,0	5490,0	-29,0	3840,0	96,5	139E3	-99,0	83,6E3	7,3

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



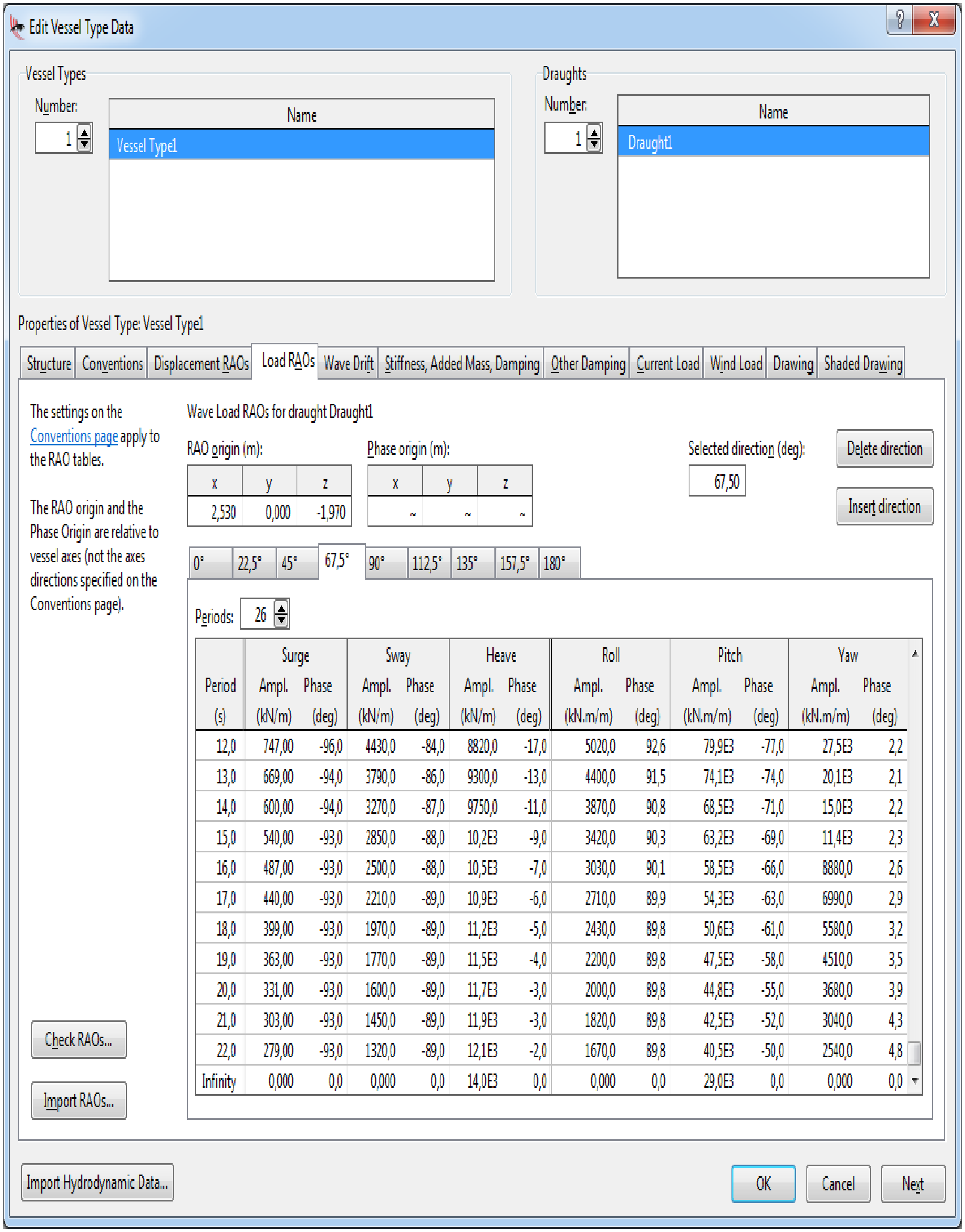
	Surge		Sway		Heave		Roll		Pitch		Yaw	
Period (s)	Ampl. (kN/m)	Phase (deg)	Ampl. (kN/m)	Phase (deg)	Ampl. (kN/m)	Phase (deg)	Ampl. (kN.m/m)	Phase (deg)	Ampl. (kN.m/m)	Phase (deg)	Ampl. (kN.m/m)	Phase (deg)
10,0	1380,0	-97,0	3850,0	-75,0	6110,0	-26,0	3920,0	95,1	139E3	-95,0	70,6E3	5,7
11,0	1330,0	-94,0	3510,0	-80,0	7130,0	-21,0	3800,0	92,7	136E3	-89,0	50,5E3	3,8
12,0	1240,0	-92,0	3100,0	-83,0	7950,0	-17,0	3490,0	91,2	131E3	-85,0	36,8E3	3,0
13,0	1150,0	-91,0	2720,0	-85,0	8640,0	-13,0	3150,0	90,3	123E3	-82,0	27,3E3	2,6
14,0	1050,0	-90,0	2390,0	-86,0	9240,0	-11,0	2820,0	89,8	114E3	-80,0	20,6E3	2,4
15,0	959,00	-90,0	2100,0	-87,0	9760,0	-9,0	2520,0	89,5	105E3	-78,0	15,8E3	2,3
16,0	873,00	-90,0	1860,0	-88,0	10,2E3	-7,0	2260,0	89,4	97,0E3	-76,0	12,3E3	2,3
17,0	794,00	-90,0	1660,0	-88,0	10,6E3	-6,0	2030,0	89,3	89,3E3	-75,0	9740,0	2,3
18,0	723,00	-90,0	1480,0	-88,0	11,0E3	-5,0	1830,0	89,3	82,4E3	-73,0	7800,0	2,4
19,0	660,00	-90,0	1340,0	-89,0	11,3E3	-4,0	1660,0	89,3	76,3E3	-71,0	6310,0	2,5
20,0	604,00	-91,0	1210,0	-89,0	11,6E3	-3,0	1510,0	89,3	70,8E3	-69,0	5170,0	2,7
21,0	555,00	-91,0	1100,0	-89,0	11,8E3	-3,0	1380,0	89,4	66,0E3	-67,0	4270,0	2,8

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



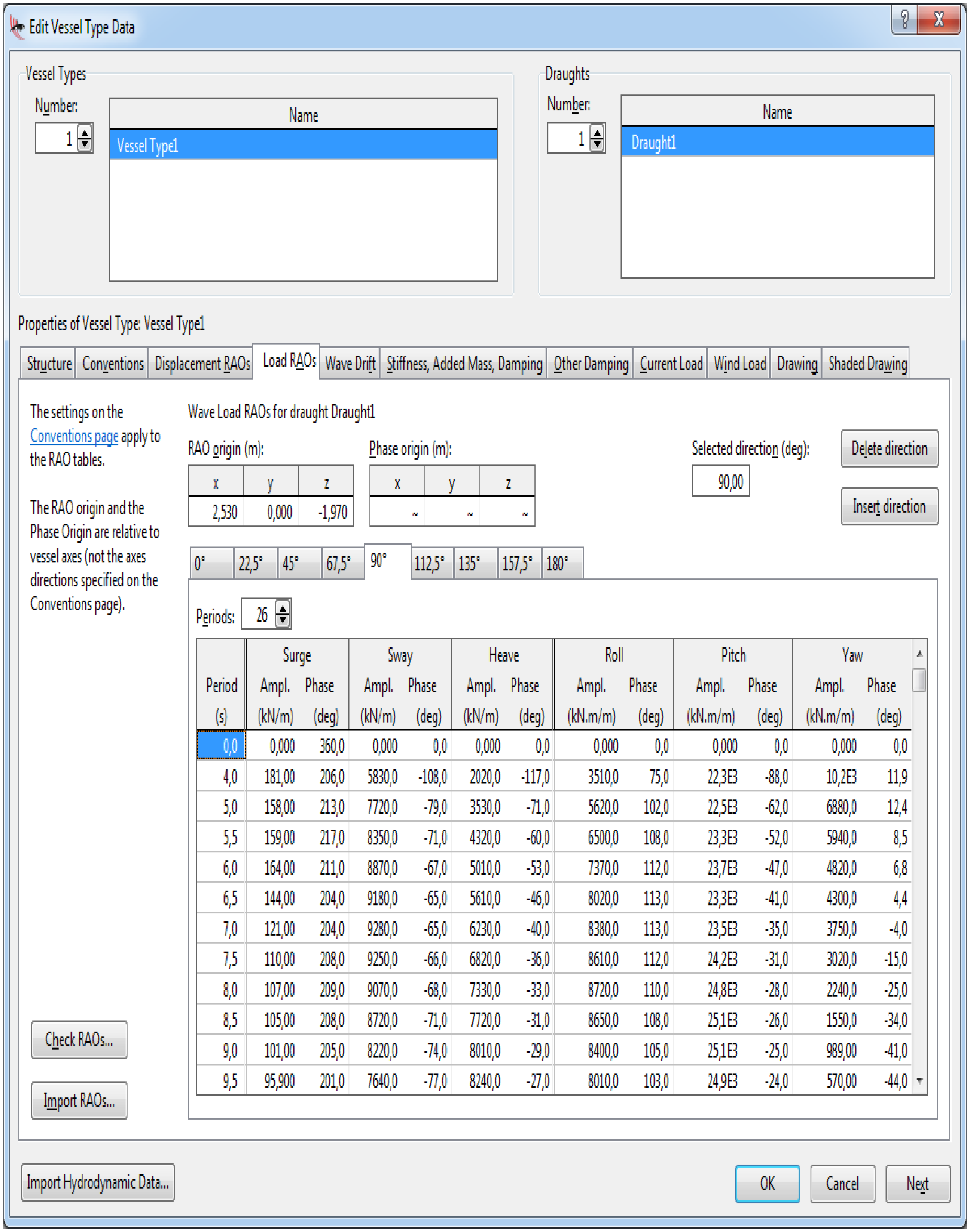
Period	Surge		Sway		Heave		Roll		Pitch		Yaw	
(s)	Ampl. (kN/m)	Phase (deg)	Ampl. (kN/m)	Phase (deg)	Ampl. (kN/m)	Phase (deg)	Ampl. (kN.m/m)	Phase (deg)	Ampl. (kN.m/m)	Phase (deg)	Ampl. (kN.m/m)	Phase (deg)
0,0	0,000	-360,0	0,000	0,0	0,000	-360,0	0,000	0,0	0,000	-360,0	0,000	0,0
4,0	631,00	-320,0	942,00	81,4	841,00	-309,5	2640,0	-113,0	34,5E3	-295,9	27,4E3	-114,0
5,0	401,00	-148,0	418,00	-80,0	579,00	-169,0	2370,0	-34,0	66,9E3	-169,0	112E3	20,6
5,5	781,00	-129,0	2080,0	-59,0	1150,0	-93,0	1660,0	17,9	89,9E3	-149,0	151E3	26,6
6,0	1040,0	-118,0	3650,0	-56,0	2180,0	-66,0	2220,0	69,5	105E3	-135,0	166E3	28,0
6,5	1240,0	-112,0	4990,0	-55,0	3260,0	-54,0	3420,0	94,0	115E3	-126,0	167E3	27,7
7,0	1330,0	-110,0	6010,0	-57,0	4230,0	-46,0	4690,0	102,0	115E3	-120,0	160E3	24,7
7,5	1310,0	-110,0	6660,0	-60,0	5110,0	-40,0	5640,0	105,0	110E3	-115,0	145E3	19,8
8,0	1240,0	-109,0	6960,0	-64,0	5870,0	-36,0	6270,0	105,0	103E3	-108,0	124E3	14,7
8,5	1160,0	-107,0	6980,0	-67,0	6490,0	-33,0	6610,0	103,0	98,5E3	-101,0	103E3	10,5
9,0	1080,0	-105,0	6790,0	-71,0	6990,0	-30,0	6700,0	101,0	95,2E3	-96,0	84,0E3	7,4
9,5	1010,0	-103,0	6450,0	-74,0	7390,0	-28,0	6590,0	99,4	92,7E3	-91,0	68,6E3	5,4

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



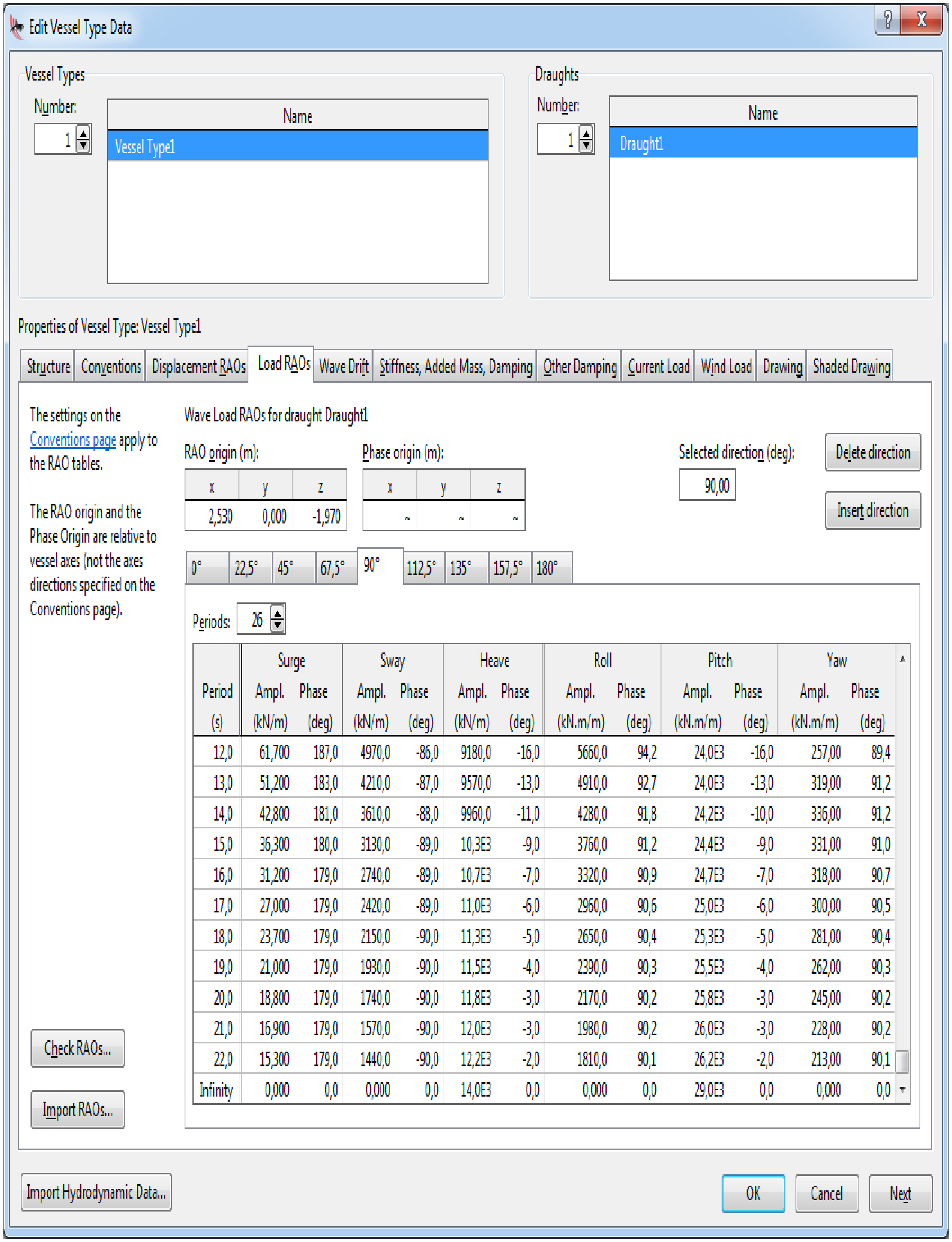
	Surge		Sway		Heave		Roll		Pitch		Yaw	
Period (s)	Ampl. (kN/m)	Phase (deg)	Ampl. (kN/m)	Phase (deg)	Ampl. (kN/m)	Phase (deg)	Ampl. (kN.m/m)	Phase (deg)	Ampl. (kN.m/m)	Phase (deg)	Ampl. (kN.m/m)	Phase (deg)
12,0	747,00	-96,0	4430,0	-84,0	8820,0	-17,0	5020,0	92,6	79,9E3	-77,0	27,5E3	2,2
13,0	669,00	-94,0	3790,0	-86,0	9300,0	-13,0	4400,0	91,5	74,1E3	-74,0	20,1E3	2,1
14,0	600,00	-94,0	3270,0	-87,0	9750,0	-11,0	3870,0	90,8	68,5E3	-71,0	15,0E3	2,2
15,0	540,00	-93,0	2850,0	-88,0	10,2E3	-9,0	3420,0	90,3	63,2E3	-69,0	11,4E3	2,3
16,0	487,00	-93,0	2500,0	-88,0	10,5E3	-7,0	3030,0	90,1	58,5E3	-66,0	8880,0	2,6
17,0	440,00	-93,0	2210,0	-89,0	10,9E3	-6,0	2710,0	89,9	54,3E3	-63,0	6990,0	2,9
18,0	399,00	-93,0	1970,0	-89,0	11,2E3	-5,0	2430,0	89,8	50,6E3	-61,0	5580,0	3,2
19,0	363,00	-93,0	1770,0	-89,0	11,5E3	-4,0	2200,0	89,8	47,5E3	-58,0	4510,0	3,5
20,0	331,00	-93,0	1600,0	-89,0	11,7E3	-3,0	2000,0	89,8	44,8E3	-55,0	3680,0	3,9
21,0	303,00	-93,0	1450,0	-89,0	11,9E3	-3,0	1820,0	89,8	42,5E3	-52,0	3040,0	4,3
22,0	279,00	-93,0	1320,0	-89,0	12,1E3	-2,0	1670,0	89,8	40,5E3	-50,0	2540,0	4,8
Infinity	0,000	0,0	0,000	0,0	14,0E3	0,0	0,000	0,0	29,0E3	0,0	0,000	0,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



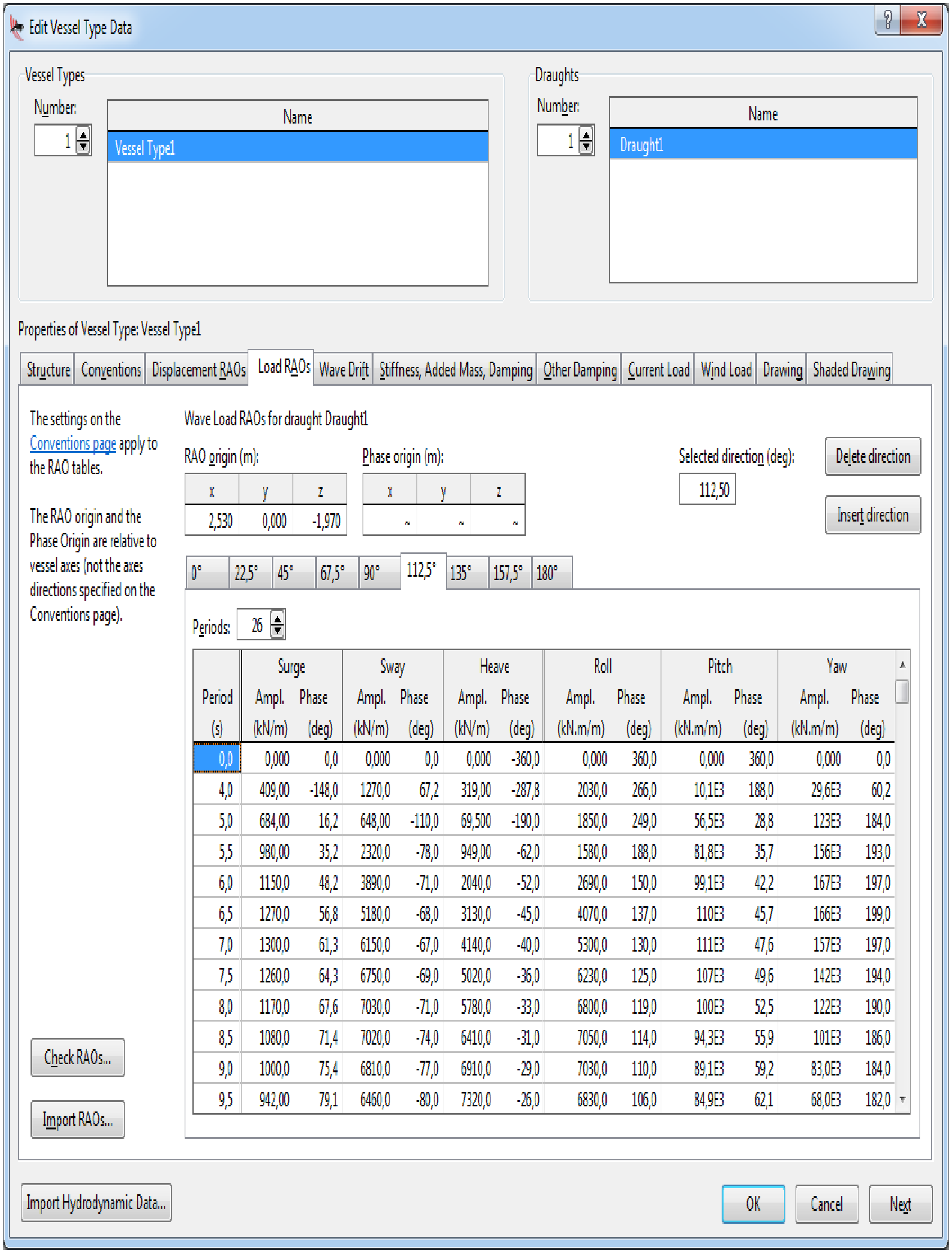
Period (s)	Surge Ampl. (kN/m)	Surge Phase (deg)	Sway Ampl. (kN/m)	Sway Phase (deg)	Heave Ampl. (kN/m)	Heave Phase (deg)	Roll Ampl. (kN.m/m)	Roll Phase (deg)	Pitch Ampl. (kN.m/m)	Pitch Phase (deg)	Yaw Ampl. (kN.m/m)	Yaw Phase (deg)
0,0	0,000	360,0	0,000	0,0	0,000	0,0	0,000	0,0	0,000	0,0	0,000	0,0
4,0	181,00	206,0	5830,0	-108,0	2020,0	-117,0	3510,0	75,0	22,3E3	-88,0	10,2E3	11,9
5,0	158,00	213,0	7720,0	-79,0	3530,0	-71,0	5620,0	102,0	22,5E3	-62,0	6880,0	12,4
5,5	159,00	217,0	8350,0	-71,0	4320,0	-60,0	6500,0	108,0	23,3E3	-52,0	5940,0	8,5
6,0	164,00	211,0	8870,0	-67,0	5010,0	-53,0	7370,0	112,0	23,7E3	-47,0	4820,0	6,8
6,5	144,00	204,0	9180,0	-65,0	5610,0	-46,0	8020,0	113,0	23,3E3	-41,0	4300,0	4,4
7,0	121,00	204,0	9280,0	-65,0	6230,0	-40,0	8380,0	113,0	23,5E3	-35,0	3750,0	-4,0
7,5	110,00	208,0	9250,0	-66,0	6820,0	-36,0	8610,0	112,0	24,2E3	-31,0	3020,0	-15,0
8,0	107,00	209,0	9070,0	-68,0	7330,0	-33,0	8720,0	110,0	24,8E3	-28,0	2240,0	-25,0
8,5	105,00	208,0	8720,0	-71,0	7720,0	-31,0	8650,0	108,0	25,1E3	-26,0	1550,0	-34,0
9,0	101,00	205,0	8220,0	-74,0	8010,0	-29,0	8400,0	105,0	25,1E3	-25,0	989,00	-41,0
9,5	95,900	201,0	7640,0	-77,0	8240,0	-27,0	8010,0	103,0	24,9E3	-24,0	570,00	-44,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



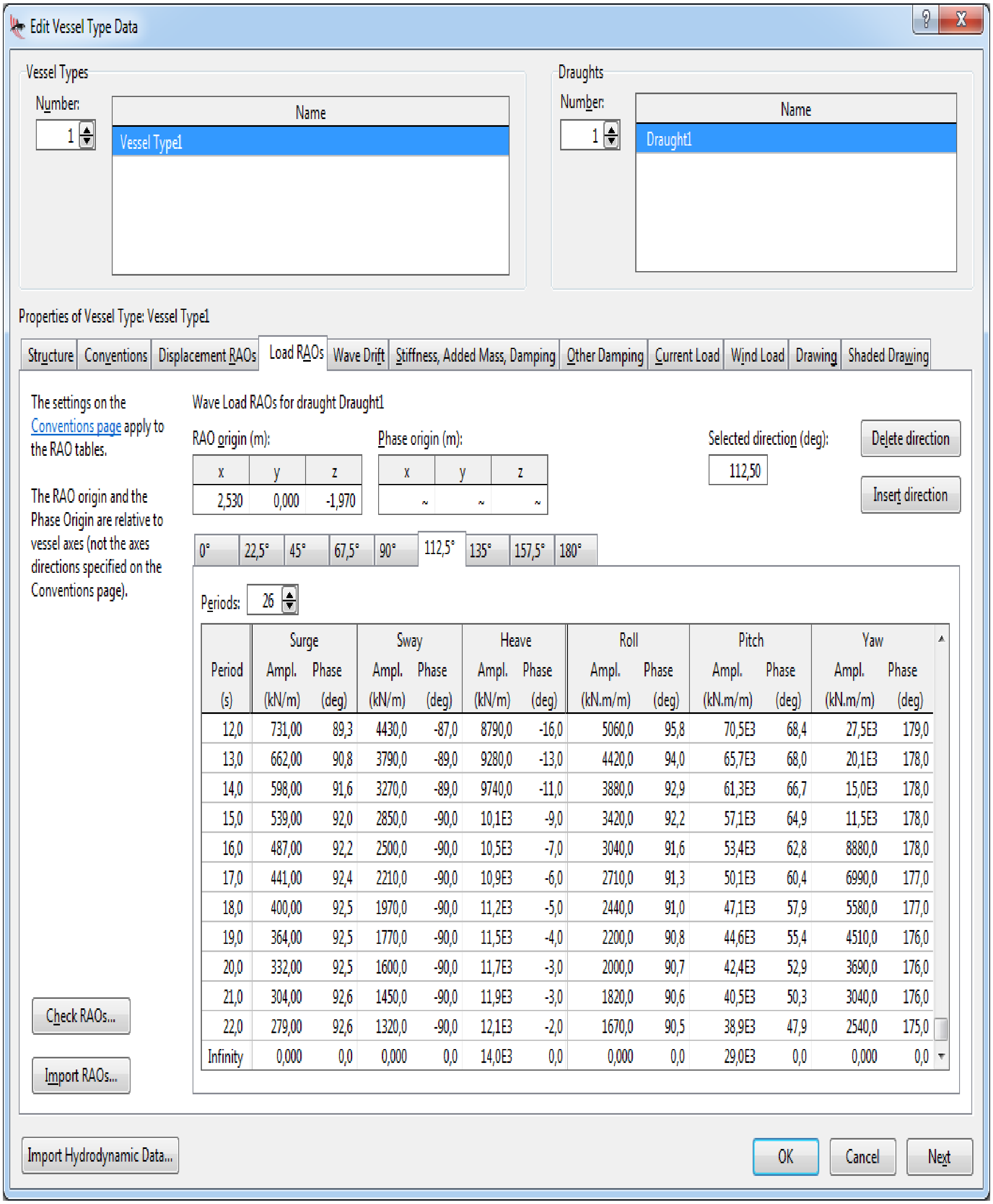
Period	Surge		Sway		Heave		Roll		Pitch		Yaw	
	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase
(s)	(kN/m)	(deg)	(kN/m)	(deg)	(kN/m)	(deg)	(kN.m/m)	(deg)	(kN.m/m)	(deg)	(kN.m/m)	(deg)
12,0	61,700	187,0	4970,0	-86,0	9180,0	-16,0	5660,0	94,2	24,0E3	-16,0	257,00	89,4
13,0	51,200	183,0	4210,0	-87,0	9570,0	-13,0	4910,0	92,7	24,0E3	-13,0	319,00	91,2
14,0	42,800	181,0	3610,0	-88,0	9960,0	-11,0	4280,0	91,8	24,2E3	-10,0	336,00	91,2
15,0	36,300	180,0	3130,0	-89,0	10,3E3	-9,0	3760,0	91,2	24,4E3	-9,0	331,00	91,0
16,0	31,200	179,0	2740,0	-89,0	10,7E3	-7,0	3320,0	90,9	24,7E3	-7,0	318,00	90,7
17,0	27,000	179,0	2420,0	-89,0	11,0E3	-6,0	2960,0	90,6	25,0E3	-6,0	300,00	90,5
18,0	23,700	179,0	2150,0	-90,0	11,3E3	-5,0	2650,0	90,4	25,3E3	-5,0	281,00	90,4
19,0	21,000	179,0	1930,0	-90,0	11,5E3	-4,0	2390,0	90,3	25,5E3	-4,0	262,00	90,3
20,0	18,800	179,0	1740,0	-90,0	11,8E3	-3,0	2170,0	90,2	25,8E3	-3,0	245,00	90,2
21,0	16,900	179,0	1570,0	-90,0	12,0E3	-3,0	1980,0	90,2	26,0E3	-3,0	228,00	90,2
22,0	15,300	179,0	1440,0	-90,0	12,2E3	-2,0	1810,0	90,1	26,2E3	-2,0	213,00	90,1
Infinity	0,000	0,0	0,000	0,0	14,0E3	0,0	0,000	0,0	29,0E3	0,0	0,000	0,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



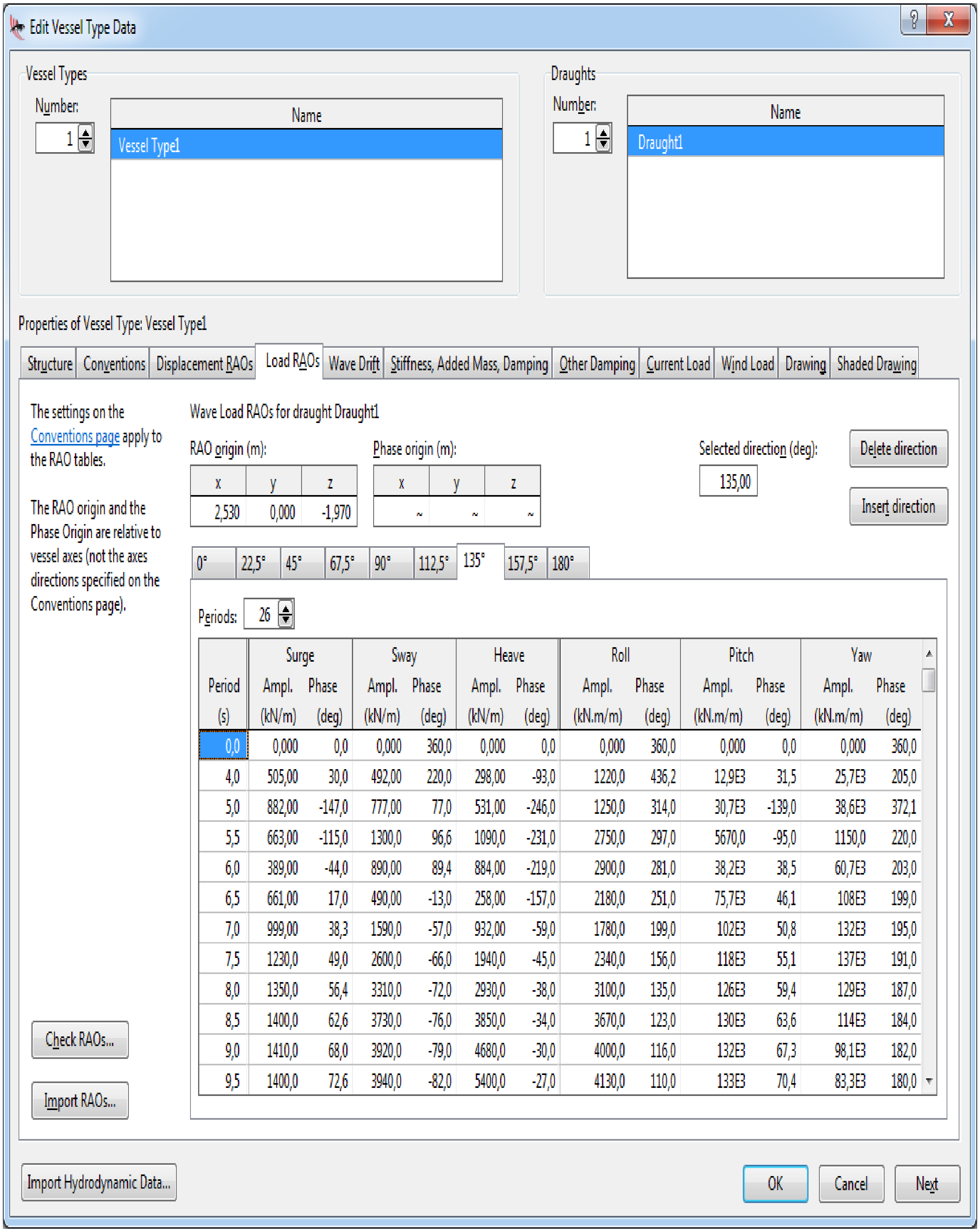
Period (s)	Surge Ampl. (kN/m)	Surge Phase (deg)	Sway Ampl. (kN/m)	Sway Phase (deg)	Heave Ampl. (kN/m)	Heave Phase (deg)	Roll Ampl. (kN.m/m)	Roll Phase (deg)	Pitch Ampl. (kN.m/m)	Pitch Phase (deg)	Yaw Ampl. (kN.m/m)	Yaw Phase (deg)
0,0	0,000	0,0	0,000	0,0	0,000	-360,0	0,000	360,0	0,000	360,0	0,000	0,0
4,0	409,00	-148,0	1270,0	67,2	319,00	-287,8	2030,0	266,0	10,1E3	188,0	29,6E3	60,2
5,0	684,00	16,2	648,00	-110,0	69,500	-190,0	1850,0	249,0	56,5E3	28,8	123E3	184,0
5,5	980,00	35,2	2320,0	-78,0	949,00	-62,0	1580,0	188,0	81,8E3	35,7	156E3	193,0
6,0	1150,0	48,2	3890,0	-71,0	2040,0	-52,0	2690,0	150,0	99,1E3	42,2	167E3	197,0
6,5	1270,0	56,8	5180,0	-68,0	3130,0	-45,0	4070,0	137,0	110E3	45,7	166E3	199,0
7,0	1300,0	61,3	6150,0	-67,0	4140,0	-40,0	5300,0	130,0	111E3	47,6	157E3	197,0
7,5	1260,0	64,3	6750,0	-69,0	5020,0	-36,0	6230,0	125,0	107E3	49,6	142E3	194,0
8,0	1170,0	67,6	7030,0	-71,0	5780,0	-33,0	6800,0	119,0	100E3	52,5	122E3	190,0
8,5	1080,0	71,4	7020,0	-74,0	6410,0	-31,0	7050,0	114,0	94,3E3	55,9	101E3	186,0
9,0	1000,0	75,4	6810,0	-77,0	6910,0	-29,0	7030,0	110,0	89,1E3	59,2	83,0E3	184,0
9,5	942,00	79,1	6460,0	-80,0	7320,0	-26,0	6830,0	106,0	84,9E3	62,1	68,0E3	182,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



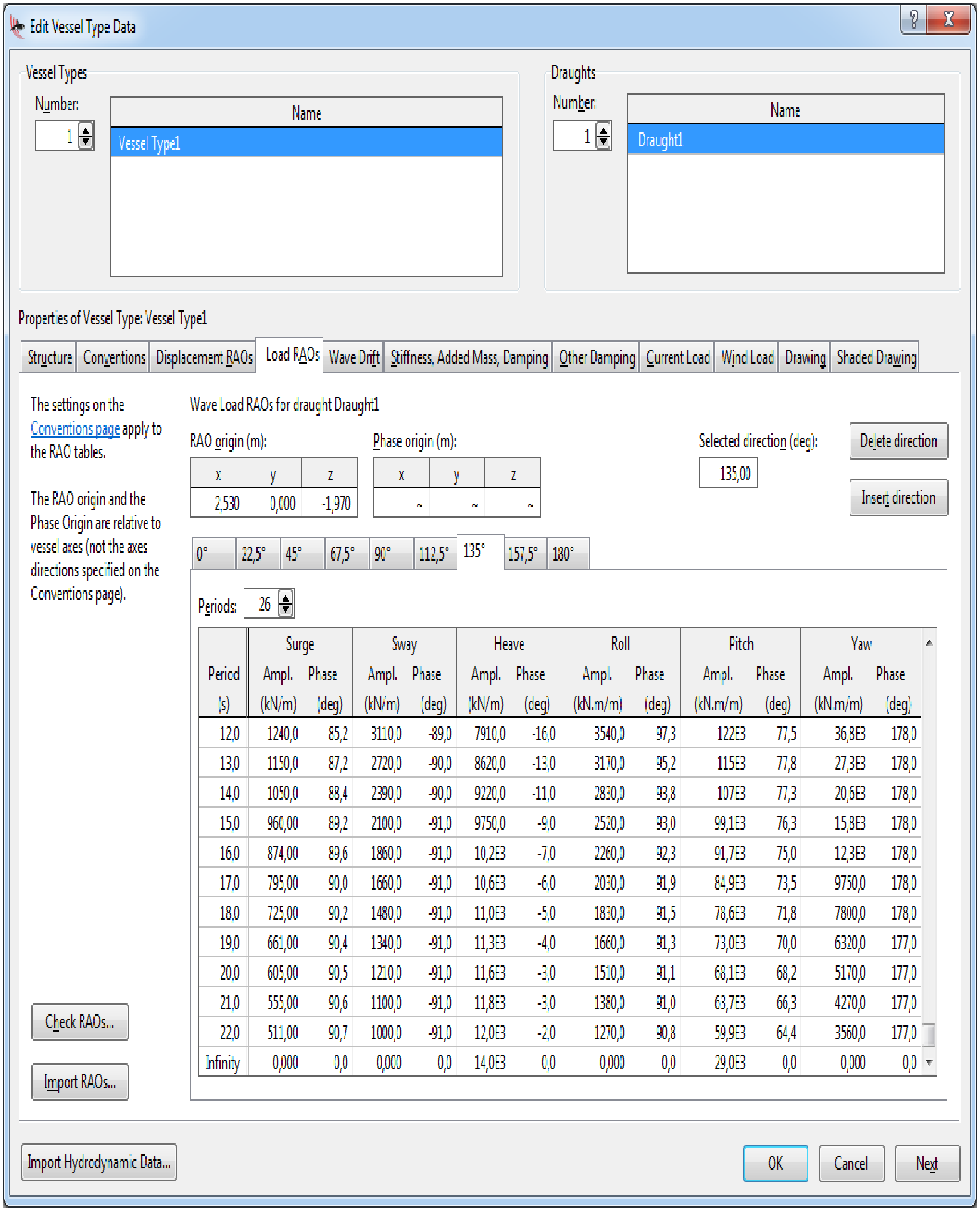
Period (s)	Surge Ampl. (kN/m)	Surge Phase (deg)	Sway Ampl. (kN/m)	Sway Phase (deg)	Heave Ampl. (kN/m)	Heave Phase (deg)	Roll Ampl. (kN.m/m)	Roll Phase (deg)	Pitch Ampl. (kN.m/m)	Pitch Phase (deg)	Yaw Ampl. (kN.m/m)	Yaw Phase (deg)
12,0	731,00	89,3	4430,0	-87,0	8790,0	-16,0	5060,0	95,8	70,5E3	68,4	27,5E3	179,0
13,0	662,00	90,8	3790,0	-89,0	9280,0	-13,0	4420,0	94,0	65,7E3	68,0	20,1E3	178,0
14,0	598,00	91,6	3270,0	-89,0	9740,0	-11,0	3880,0	92,9	61,3E3	66,7	15,0E3	178,0
15,0	539,00	92,0	2850,0	-90,0	10,1E3	-9,0	3420,0	92,2	57,1E3	64,9	11,5E3	178,0
16,0	487,00	92,2	2500,0	-90,0	10,5E3	-7,0	3040,0	91,6	53,4E3	62,8	8880,0	178,0
17,0	441,00	92,4	2210,0	-90,0	10,9E3	-6,0	2710,0	91,3	50,1E3	60,4	6990,0	177,0
18,0	400,00	92,5	1970,0	-90,0	11,2E3	-5,0	2440,0	91,0	47,1E3	57,9	5580,0	177,0
19,0	364,00	92,5	1770,0	-90,0	11,5E3	-4,0	2200,0	90,8	44,6E3	55,4	4510,0	176,0
20,0	332,00	92,5	1600,0	-90,0	11,7E3	-3,0	2000,0	90,7	42,4E3	52,9	3690,0	176,0
21,0	304,00	92,6	1450,0	-90,0	11,9E3	-3,0	1820,0	90,6	40,5E3	50,3	3040,0	176,0
22,0	279,00	92,6	1320,0	-90,0	12,1E3	-2,0	1670,0	90,5	38,9E3	47,9	2540,0	175,0
Infinity	0,000	0,0	0,000	0,0	14,0E3	0,0	0,000	0,0	29,0E3	0,0	0,000	0,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



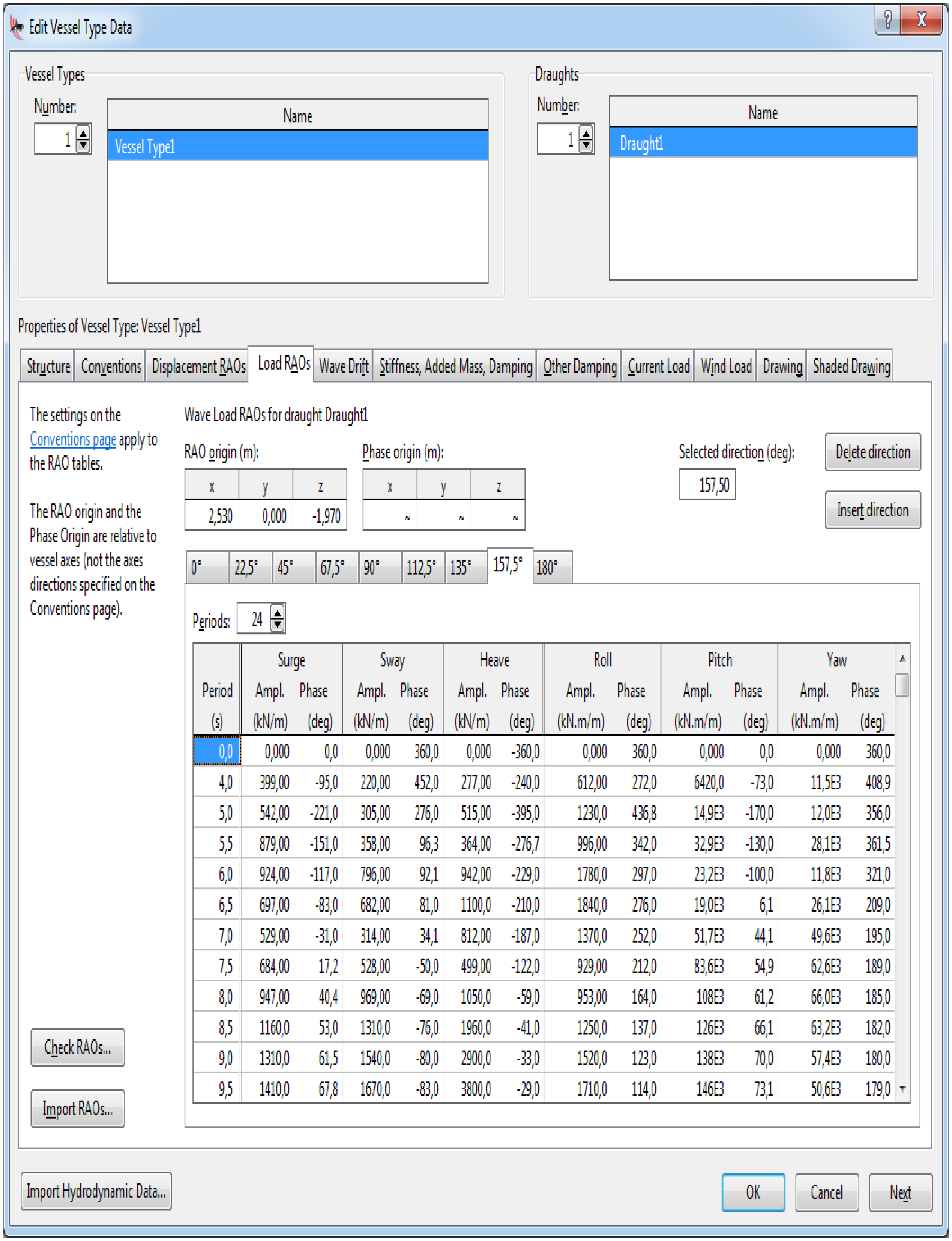
Period	Surge		Sway		Heave		Roll		Pitch		Yaw	
(s)	Ampl. (kN/m)	Phase (deg)	Ampl. (kN/m)	Phase (deg)	Ampl. (kN/m)	Phase (deg)	Ampl. (kN.m/m)	Phase (deg)	Ampl. (kN.m/m)	Phase (deg)	Ampl. (kN.m/m)	Phase (deg)
0,0	0,000	0,0	0,000	360,0	0,000	0,0	0,000	360,0	0,000	0,0	0,000	360,0
4,0	505,00	30,0	492,00	220,0	298,00	-93,0	1220,0	436,2	12,9E3	31,5	25,7E3	205,0
5,0	882,00	-147,0	777,00	77,0	531,00	-246,0	1250,0	314,0	30,7E3	-139,0	38,6E3	372,1
5,5	663,00	-115,0	1300,0	96,6	1090,0	-231,0	2750,0	297,0	5670,0	-95,0	1150,0	220,0
6,0	389,00	-44,0	890,00	89,4	884,00	-219,0	2900,0	281,0	38,2E3	38,5	60,7E3	203,0
6,5	661,00	17,0	490,00	-13,0	258,00	-157,0	2180,0	251,0	75,7E3	46,1	108E3	199,0
7,0	999,00	38,3	1590,0	-57,0	932,00	-59,0	1780,0	199,0	102E3	50,8	132E3	195,0
7,5	1230,0	49,0	2600,0	-66,0	1940,0	-45,0	2340,0	156,0	118E3	55,1	137E3	191,0
8,0	1350,0	56,4	3310,0	-72,0	2930,0	-38,0	3100,0	135,0	126E3	59,4	129E3	187,0
8,5	1400,0	62,6	3730,0	-76,0	3850,0	-34,0	3670,0	123,0	130E3	63,6	114E3	184,0
9,0	1410,0	68,0	3920,0	-79,0	4680,0	-30,0	4000,0	116,0	132E3	67,3	98,1E3	182,0
9,5	1400,0	72,6	3940,0	-82,0	5400,0	-27,0	4130,0	110,0	133E3	70,4	83,3E3	180,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



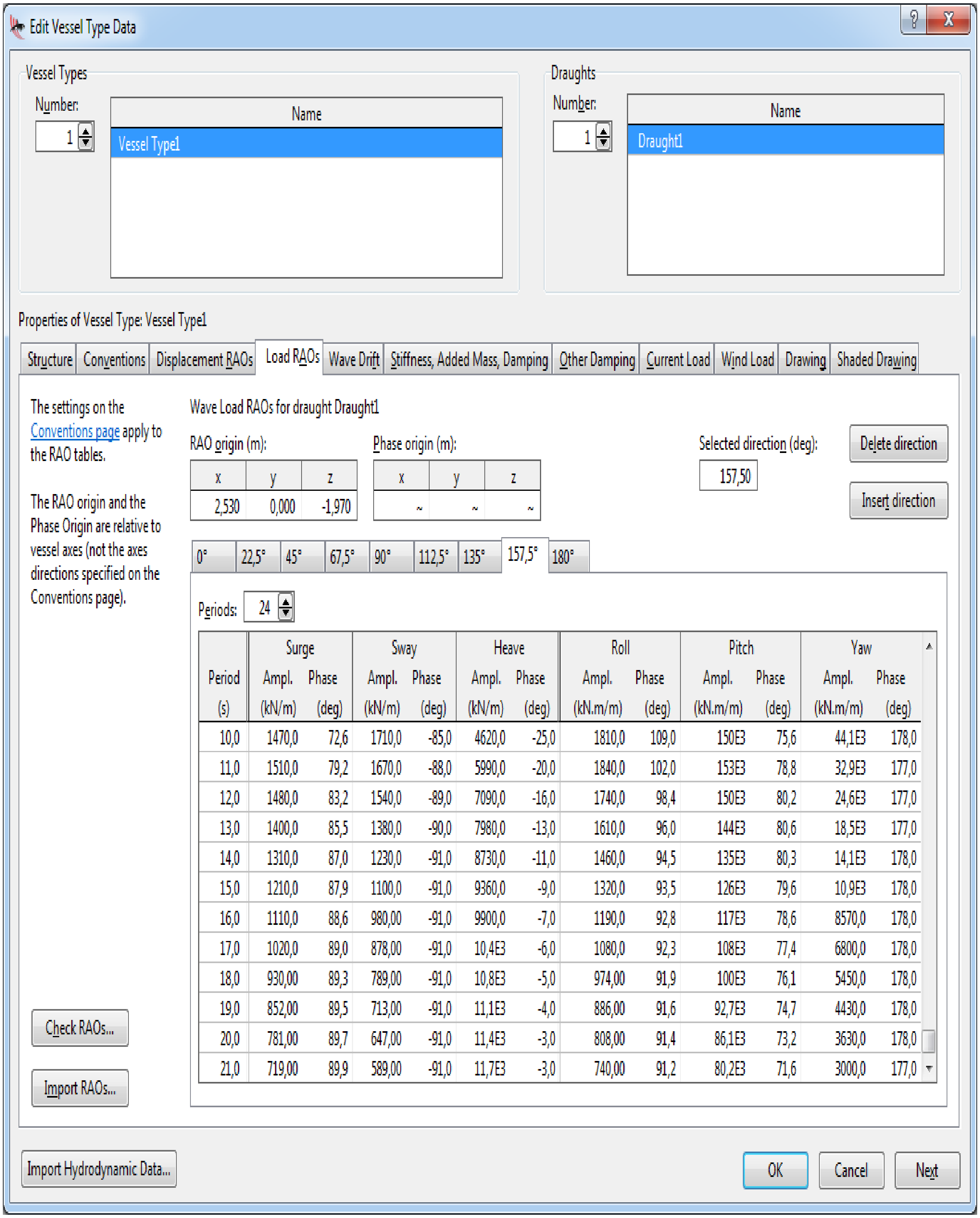
Period	Surge		Sway		Heave		Roll		Pitch		Yaw	
	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase
(s)	(kN/m)	(deg)	(kN/m)	(deg)	(kN/m)	(deg)	(kN.m/m)	(deg)	(kN.m/m)	(deg)	(kN.m/m)	(deg)
12,0	1240,0	85,2	3110,0	-89,0	7910,0	-16,0	3540,0	97,3	122E3	77,5	36,8E3	178,0
13,0	1150,0	87,2	2720,0	-90,0	8620,0	-13,0	3170,0	95,2	115E3	77,8	27,3E3	178,0
14,0	1050,0	88,4	2390,0	-90,0	9220,0	-11,0	2830,0	93,8	107E3	77,3	20,6E3	178,0
15,0	960,00	89,2	2100,0	-91,0	9750,0	-9,0	2520,0	93,0	99,1E3	76,3	15,8E3	178,0
16,0	874,00	89,6	1860,0	-91,0	10,2E3	-7,0	2260,0	92,3	91,7E3	75,0	12,3E3	178,0
17,0	795,00	90,0	1660,0	-91,0	10,6E3	-6,0	2030,0	91,9	84,9E3	73,5	9750,0	178,0
18,0	725,00	90,2	1480,0	-91,0	11,0E3	-5,0	1830,0	91,5	78,6E3	71,8	7800,0	178,0
19,0	661,00	90,4	1340,0	-91,0	11,3E3	-4,0	1660,0	91,3	73,0E3	70,0	6320,0	177,0
20,0	605,00	90,5	1210,0	-91,0	11,6E3	-3,0	1510,0	91,1	68,1E3	68,2	5170,0	177,0
21,0	555,00	90,6	1100,0	-91,0	11,8E3	-3,0	1380,0	91,0	63,7E3	66,3	4270,0	177,0
22,0	511,00	90,7	1000,0	-91,0	12,0E3	-2,0	1270,0	90,8	59,9E3	64,4	3560,0	177,0
Infinity	0,000	0,0	0,000	0,0	14,0E3	0,0	0,000	0,0	29,0E3	0,0	0,000	0,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



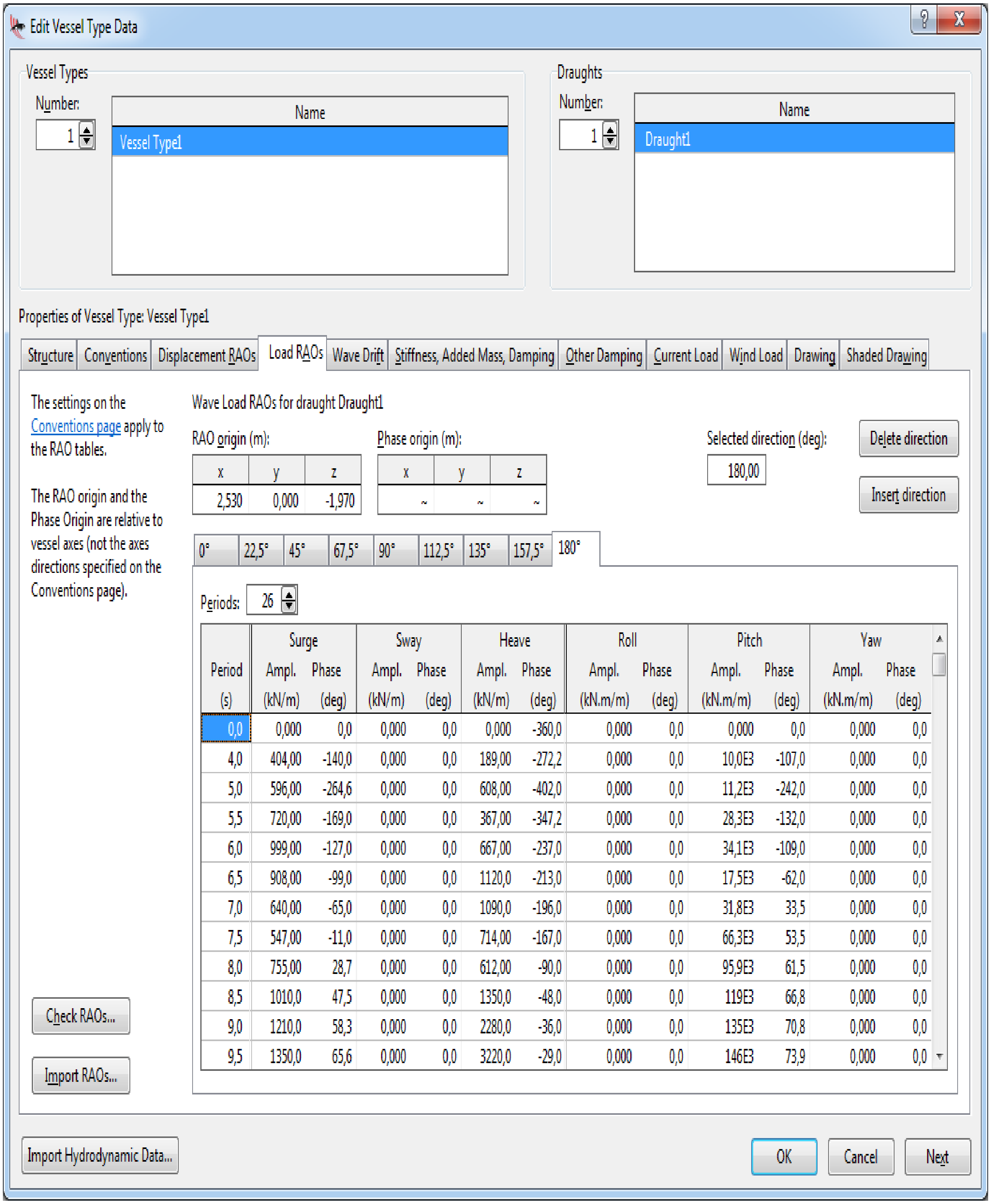
Period	Surge		Sway		Heave		Roll		Pitch		Yaw	
	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase
(s)	(kN/m)	(deg)	(kN/m)	(deg)	(kN/m)	(deg)	(kN.m/m)	(deg)	(kN.m/m)	(deg)	(kN.m/m)	(deg)
0,0	0,000	0,0	0,000	360,0	0,000	-360,0	0,000	360,0	0,000	0,0	0,000	360,0
4,0	399,00	-95,0	220,00	452,0	277,00	-240,0	612,00	272,0	6420,0	-73,0	11,5E3	408,9
5,0	542,00	-221,0	305,00	276,0	515,00	-395,0	1230,0	436,8	14,9E3	-170,0	12,0E3	356,0
5,5	879,00	-151,0	358,00	96,3	364,00	-276,7	996,00	342,0	32,9E3	-130,0	28,1E3	361,5
6,0	924,00	-117,0	796,00	92,1	942,00	-229,0	1780,0	297,0	23,2E3	-100,0	11,8E3	321,0
6,5	697,00	-83,0	682,00	81,0	1100,0	-210,0	1840,0	276,0	19,0E3	6,1	26,1E3	209,0
7,0	529,00	-31,0	314,00	34,1	812,00	-187,0	1370,0	252,0	51,7E3	44,1	49,6E3	195,0
7,5	684,00	17,2	528,00	-50,0	499,00	-122,0	929,00	212,0	83,6E3	54,9	62,6E3	189,0
8,0	947,00	40,4	969,00	-69,0	1050,0	-59,0	953,00	164,0	108E3	61,2	66,0E3	185,0
8,5	1160,0	53,0	1310,0	-76,0	1960,0	-41,0	1250,0	137,0	126E3	66,1	63,2E3	182,0
9,0	1310,0	61,5	1540,0	-80,0	2900,0	-33,0	1520,0	123,0	138E3	70,0	57,4E3	180,0
9,5	1410,0	67,8	1670,0	-83,0	3800,0	-29,0	1710,0	114,0	146E3	73,1	50,6E3	179,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



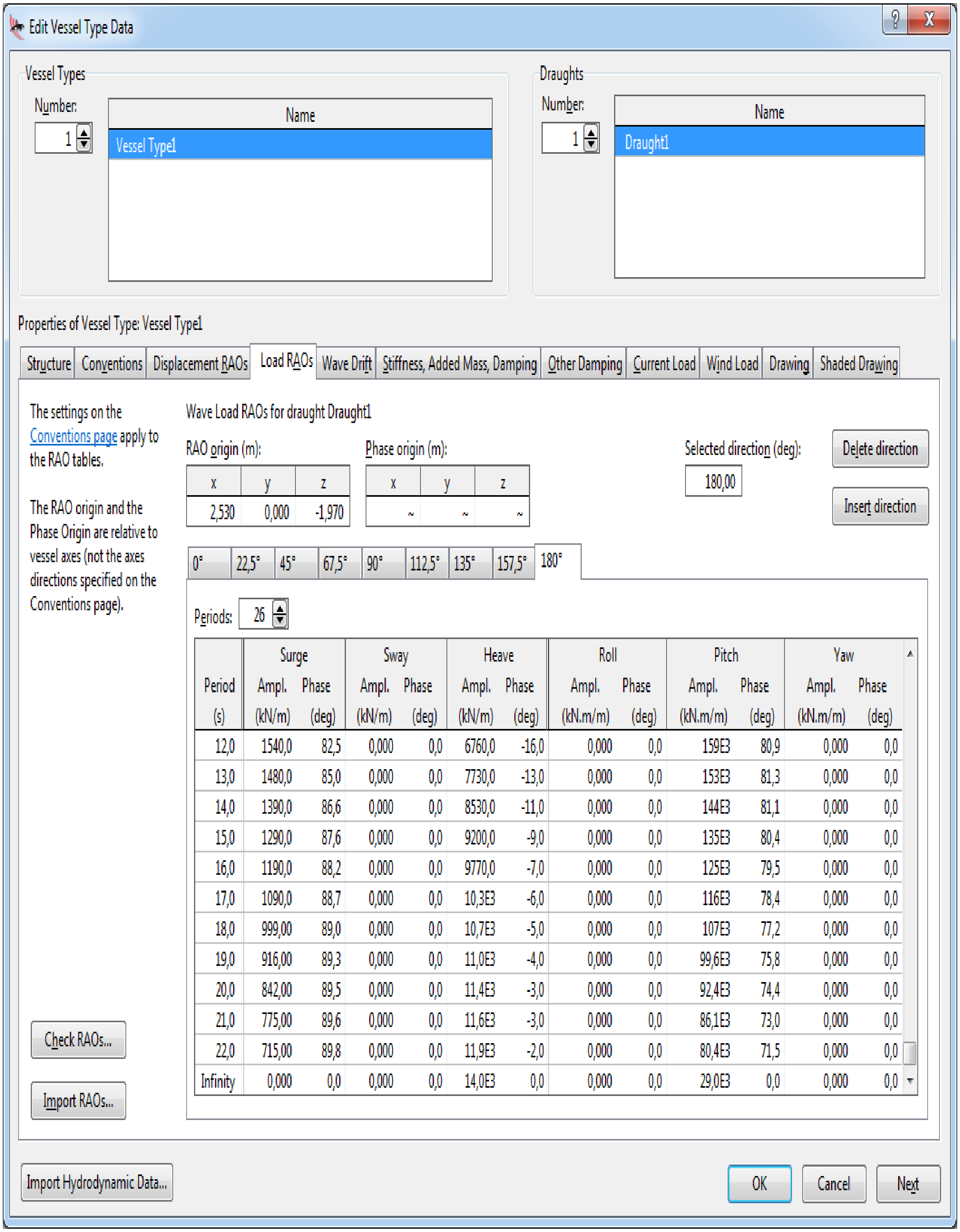
Period	Surge		Sway		Heave		Roll		Pitch		Yaw	
(s)	Ampl. (kN/m)	Phase (deg)	Ampl. (kN/m)	Phase (deg)	Ampl. (kN/m)	Phase (deg)	Ampl. (kN.m/m)	Phase (deg)	Ampl. (kN.m/m)	Phase (deg)	Ampl. (kN.m/m)	Phase (deg)
10,0	1470,0	72,6	1710,0	-85,0	4620,0	-25,0	1810,0	109,0	150E3	75,6	44,1E3	178,0
11,0	1510,0	79,2	1670,0	-88,0	5990,0	-20,0	1840,0	102,0	153E3	78,8	32,9E3	177,0
12,0	1480,0	83,2	1540,0	-89,0	7090,0	-16,0	1740,0	98,4	150E3	80,2	24,6E3	177,0
13,0	1400,0	85,5	1380,0	-90,0	7980,0	-13,0	1610,0	96,0	144E3	80,6	18,5E3	177,0
14,0	1310,0	87,0	1230,0	-91,0	8730,0	-11,0	1460,0	94,5	135E3	80,3	14,1E3	178,0
15,0	1210,0	87,9	1100,0	-91,0	9360,0	-9,0	1320,0	93,5	126E3	79,6	10,9E3	178,0
16,0	1110,0	88,6	980,00	-91,0	9900,0	-7,0	1190,0	92,8	117E3	78,6	8570,0	178,0
17,0	1020,0	89,0	878,00	-91,0	10,4E3	-6,0	1080,0	92,3	108E3	77,4	6800,0	178,0
18,0	930,00	89,3	789,00	-91,0	10,8E3	-5,0	974,00	91,9	100E3	76,1	5450,0	178,0
19,0	852,00	89,5	713,00	-91,0	11,1E3	-4,0	886,00	91,6	92,7E3	74,7	4430,0	178,0
20,0	781,00	89,7	647,00	-91,0	11,4E3	-3,0	808,00	91,4	86,1E3	73,2	3630,0	178,0
21,0	719,00	89,9	589,00	-91,0	11,7E3	-3,0	740,00	91,2	80,2E3	71,6	3000,0	177,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



Period (s)	Surge Ampl. (kN/m)	Surge Phase (deg)	Sway Ampl. (kN/m)	Sway Phase (deg)	Heave Ampl. (kN/m)	Heave Phase (deg)	Roll Ampl. (kN.m/m)	Roll Phase (deg)	Pitch Ampl. (kN.m/m)	Pitch Phase (deg)	Yaw Ampl. (kN.m/m)	Yaw Phase (deg)
0,0	0,000	0,0	0,000	0,0	0,000	-360,0	0,000	0,0	0,000	0,0	0,000	0,0
4,0	404,00	-140,0	0,000	0,0	189,00	-272,2	0,000	0,0	10,0E3	-107,0	0,000	0,0
5,0	596,00	-264,6	0,000	0,0	608,00	-402,0	0,000	0,0	11,2E3	-242,0	0,000	0,0
5,5	720,00	-169,0	0,000	0,0	367,00	-347,2	0,000	0,0	28,3E3	-132,0	0,000	0,0
6,0	999,00	-127,0	0,000	0,0	667,00	-237,0	0,000	0,0	34,1E3	-109,0	0,000	0,0
6,5	908,00	-99,0	0,000	0,0	1120,0	-213,0	0,000	0,0	17,5E3	-62,0	0,000	0,0
7,0	640,00	-65,0	0,000	0,0	1090,0	-196,0	0,000	0,0	31,8E3	33,5	0,000	0,0
7,5	547,00	-11,0	0,000	0,0	714,00	-167,0	0,000	0,0	66,3E3	53,5	0,000	0,0
8,0	755,00	28,7	0,000	0,0	612,00	-90,0	0,000	0,0	95,9E3	61,5	0,000	0,0
8,5	1010,0	47,5	0,000	0,0	1350,0	-48,0	0,000	0,0	119E3	66,8	0,000	0,0
9,0	1210,0	58,3	0,000	0,0	2280,0	-36,0	0,000	0,0	135E3	70,8	0,000	0,0
9,5	1350,0	65,6	0,000	0,0	3220,0	-29,0	0,000	0,0	146E3	73,9	0,000	0,0

Appendix 1: Vessel RAO, s (Response Amplitude Operators) for Case 1, Case 2 and Case 3



Period	Surge		Sway		Heave		Roll		Pitch		Yaw	
	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase	Ampl.	Phase
(s)	(kN/m)	(deg)	(kN/m)	(deg)	(kN/m)	(deg)	(kN.m/m)	(deg)	(kN.m/m)	(deg)	(kN.m/m)	(deg)
12,0	1540,0	82,5	0,000	0,0	6760,0	-16,0	0,000	0,0	159E3	80,9	0,000	0,0
13,0	1480,0	85,0	0,000	0,0	7730,0	-13,0	0,000	0,0	153E3	81,3	0,000	0,0
14,0	1390,0	86,6	0,000	0,0	8530,0	-11,0	0,000	0,0	144E3	81,1	0,000	0,0
15,0	1290,0	87,6	0,000	0,0	9200,0	-9,0	0,000	0,0	135E3	80,4	0,000	0,0
16,0	1190,0	88,2	0,000	0,0	9770,0	-7,0	0,000	0,0	125E3	79,5	0,000	0,0
17,0	1090,0	88,7	0,000	0,0	10,3E3	-6,0	0,000	0,0	116E3	78,4	0,000	0,0
18,0	999,00	89,0	0,000	0,0	10,7E3	-5,0	0,000	0,0	107E3	77,2	0,000	0,0
19,0	916,00	89,3	0,000	0,0	11,0E3	-4,0	0,000	0,0	99,6E3	75,8	0,000	0,0
20,0	842,00	89,5	0,000	0,0	11,4E3	-3,0	0,000	0,0	92,4E3	74,4	0,000	0,0
21,0	775,00	89,6	0,000	0,0	11,6E3	-3,0	0,000	0,0	86,1E3	73,0	0,000	0,0
22,0	715,00	89,8	0,000	0,0	11,9E3	-2,0	0,000	0,0	80,4E3	71,5	0,000	0,0
Infinity	0,000	0,0	0,000	0,0	14,0E3	0,0	0,000	0,0	29,0E3	0,0	0,000	0,0

Appendix 2A: Range graph values for case 1 (Line 1)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
0.0	87.3289	142.6094	116.849	18.2578
2.5	86.5493	141.4672	115.8679	18.1204
7.5	96.6296	140.3886	120.4437	14.4957
12.5	94.2287	138.4371	118.2473	14.6658
17.5	91.846	136.4898	116.0558	14.8304
22.5	89.492	134.5387	113.8692	14.9876
27.5	87.1654	132.5797	111.6873	15.1368
32.5	84.8361	130.6129	109.5105	15.2776
37.5	82.5021	128.646	107.3393	15.4108
42.5	80.1969	126.6788	105.174	15.5373
47.5	77.9154	124.7104	103.0157	15.6581
52.5	75.6301	122.745	100.8653	15.7744
57.5	73.3693	120.7869	98.7235	15.8875
62.5	71.1307	118.8344	96.5916	15.9986
67.5	68.8998	116.8904	94.4706	16.1085
72.5	66.6562	114.9532	92.3618	16.2186
77.5	64.394	113.0229	90.2665	16.3294
82.5	62.1368	111.111	88.186	16.4417
87.5	59.8438	109.237	86.1218	16.556
92.5	57.5722	107.3819	84.0753	16.6727
97.5	55.317	105.5473	82.0485	16.7916
105.0	54.1711	104.6242	81.0238	16.8538
115.0	54.1267	104.5913	80.9833	16.8546
125.0	54.0833	104.5586	80.943	16.8553
135.0	54.0391	104.5261	80.9029	16.8562
145.0	53.9941	104.4938	80.8629	16.8572
155.0	53.9488	104.4616	80.823	16.8583
165.0	53.9036	104.4295	80.7832	16.8595
175.0	53.8593	104.3974	80.7434	16.8608
185.0	53.8165	104.3653	80.7037	16.8621
195.0	53.7759	104.3332	80.664	16.8635
205.0	53.7373	104.3009	80.6243	16.8648
215.0	53.6998	104.2687	80.5847	16.8661
225.0	53.6614	104.2363	80.5451	16.8674
235.0	53.6214	104.2038	80.5056	16.8686
245.0	53.5802	104.1711	80.466	16.8697
255.0	53.5358	104.1382	80.4265	16.8707
265.0	53.488	104.1052	80.3871	16.8715
275.0	53.4405	104.0719	80.3476	16.8723
285.0	53.3947	104.0383	80.3081	16.8729
295.0	53.351	104.0046	80.2687	16.8733
305.0	53.3094	103.9707	80.2293	16.8736
315.0	53.2699	103.9365	80.19	16.8737
325.0	53.2322	103.9021	80.1506	16.8736

Appendix 2A: Range graph values for case 1 (Line 1)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
335.0	53.1961	103.8674	80.1113	16.8733
345.0	53.1614	103.8325	80.072	16.8728
355.0	53.1276	103.7973	80.0328	16.8721
365.0	53.0939	103.762	79.9936	16.8712
375.0	53.059	103.7263	79.9544	16.8701
385.0	53.0244	103.6904	79.9152	16.8687
395.0	52.9907	103.6542	79.876	16.8672
405.0	52.9579	103.6177	79.8369	16.8654
415.0	52.926	103.5809	79.7979	16.8633
425.0	52.8948	103.5438	79.7589	16.861
435.0	52.8646	103.5064	79.72	16.8584
445.0	52.8353	103.4688	79.6811	16.8555
455.0	52.8066	103.4308	79.6423	16.8523
465.0	52.7734	103.3925	79.6035	16.8488
475.0	52.7397	103.354	79.5648	16.8451
485.0	52.7063	103.3152	79.5261	16.8412
495.0	52.674	103.276	79.4875	16.8369
505.0	52.6435	103.2365	79.449	16.8323
515.0	52.6146	103.1968	79.4105	16.8274
525.0	52.5876	103.1567	79.3722	16.8222
535.0	52.5626	103.1163	79.3339	16.8167
545.0	52.5394	103.0755	79.2958	16.8109
555.0	52.518	103.0345	79.2577	16.8047
565.0	52.4981	102.9932	79.2197	16.7982
575.0	52.4796	102.9516	79.1819	16.7915
585.0	52.4622	102.9097	79.1441	16.7844
595.0	52.4423	102.8676	79.1065	16.777
602.5	51.4362	101.8995	78.1385	16.752
607.5	49.3532	100.032	76.2614	16.7143
612.5	47.3293	98.1969	74.4129	16.6801
617.5	45.3696	96.3978	72.5955	16.6499
622.5	43.4764	94.6377	70.8133	16.6221
627.5	41.6525	92.9173	69.068	16.5986
632.5	39.8986	91.2413	67.3638	16.5783
637.5	38.212	89.612	65.7034	16.5634
642.5	36.5895	88.0335	64.0904	16.5544
647.5	35.0318	86.51	62.5297	16.5507
652.5	33.5373	85.0457	61.0236	16.5553
657.5	32.1048	83.6449	59.5783	16.5663
662.5	30.7359	82.3126	58.1955	16.5886
667.5	29.4317	81.0532	56.8817	16.6188
672.5	28.1937	79.8694	55.6424	16.6558
677.5	27.0222	78.763	54.4821	16.6989
682.5	25.9191	77.7373	53.4054	16.7473
687.5	24.8876	76.7969	52.4178	16.7981

Appendix 2A: Range graph values for case 1 (Line 1)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
692.5	23.9323	75.9448	51.525	16.8473
697.5	23.0602	75.1798	50.7322	16.8902
702.5	22.2819	74.4982	50.0454	16.9196
707.5	21.6131	73.8993	49.4689	16.9297
712.5	21.0887	73.3871	49.0086	16.9115
717.5	20.7702	72.9648	48.6587	16.8673
722.5	20.8308	72.6283	48.3522	16.832
727.5	21.0391	72.3677	48.0863	16.7671
732.5	21.4101	72.1793	47.9034	16.6164
737.5	22.0208	72.0662	47.8284	16.3483
742.5	22.9026	72.0299	47.8913	15.94
747.5	23.9486	71.2562	48.1678	15.4062
752.5	24.9234	70.9537	48.4483	14.9604
757.5	25.8787	70.733	48.7468	14.5487
762.5	26.8229	70.5546	49.0576	14.1588
767.5	27.7517	70.4162	49.3762	13.7872
772.5	28.6657	70.314	49.7004	13.4298
777.5	29.5584	70.2604	49.9857	13.1156
782.5	30.4234	70.2168	50.2423	12.8419
787.5	31.2655	70.1821	50.499	12.588
792.5	32.0647	70.1547	50.7559	12.3525
797.5	31.1716	70.1299	51.0149	12.1376
802.5	30.2848	70.0558	51.2144	11.972
807.5	29.4431	70.0156	51.3478	11.8351
812.5	28.658	69.8633	51.3792	11.724
817.5	27.9282	69.7107	51.235	11.6237
822.5	27.2514	69.539	50.7975	11.4906
827.5	26.626	68.561	50.0539	11.2939
832.5	26.05	67.4382	49.2561	11.0913
837.5	25.5219	66.3046	48.4373	10.8934
842.5	25.0404	65.1698	47.6029	10.6992
847.5	24.6047	64.035	46.7763	10.5053
852.5	24.2141	63.003	46.0321	10.3291
857.5	23.868	62.0831	45.3698	10.1712
862.5	23.566	61.2735	44.7883	10.0315
867.5	23.3079	60.5729	44.2857	9.9105
872.5	23.0933	59.98	43.863	9.8061
877.5	22.922	59.4936	43.5182	9.7195
882.5	22.7935	59.1131	43.2512	9.6499
887.5	22.7077	58.8376	43.0611	9.5976
892.5	22.6644	58.6669	42.9479	9.5622
897.5	22.6652	58.6038	42.9135	9.5446
900.0	22.7043	58.6408	42.9514	9.5441

Appendix 2A: Range graph values for case 1 (Line 2)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
0.0	69.9189	97.8519	85.5922	8.5652
2.5	68.809	96.8365	84.4493	8.5977
7.5	67.1455	109.4205	89.7855	13.6492
12.5	64.9402	107.377	87.6216	13.7366
17.5	62.7319	105.3394	85.4562	13.8297
22.5	60.5289	103.306	83.2892	13.9275
27.5	58.3373	101.2852	81.1215	14.0287
32.5	56.0938	99.3123	78.9544	14.1316
37.5	53.7457	97.3569	76.7887	14.236
42.5	51.375	95.4131	74.6252	14.342
47.5	49.0138	93.4754	72.4649	14.4497
52.5	46.6639	91.5426	70.3087	14.5592
57.5	44.3264	89.6148	68.158	14.671
62.5	42.0016	87.7046	66.0144	14.785
67.5	39.6893	85.808	63.8793	14.9018
72.5	37.3904	83.9225	61.7531	15.0221
77.5	35.1081	82.0519	59.6383	15.1454
82.5	32.8462	80.197	57.5368	15.2712
87.5	30.6087	78.3596	55.4505	15.3998
92.5	28.4004	76.5481	53.382	15.5305
97.5	26.2263	74.767	51.3342	15.6624
105.0	25.1354	73.8631	50.293	15.7262
115.0	25.1126	73.8161	50.2422	15.7216
125.0	25.1009	73.7675	50.1913	15.7163
135.0	25.092	73.7177	50.1405	15.7105
145.0	25.0833	73.6669	50.0898	15.7039
155.0	25.0815	73.6155	50.0392	15.6968
165.0	25.0902	73.5639	49.9886	15.6894
175.0	25.1066	73.5123	49.9382	15.6816
185.0	25.1194	73.4611	49.8877	15.6737
195.0	25.1224	73.4102	49.8372	15.6656
205.0	25.1005	73.3596	49.787	15.6573
215.0	25.0574	73.3094	49.7372	15.6487
225.0	25.0242	73.2594	49.6874	15.6405
235.0	24.999	73.2092	49.6378	15.6322
245.0	24.96	73.1588	49.5882	15.6238
255.0	24.9149	73.1079	49.5388	15.6156
265.0	24.8798	73.0565	49.4897	15.6068
275.0	24.8558	73.0044	49.4407	15.5979
285.0	24.8395	72.9517	49.3917	15.5889
295.0	24.8042	72.8983	49.3425	15.58
305.0	24.7688	72.8442	49.2931	15.5711
315.0	24.7433	72.7894	49.244	15.5621

Appendix 2A: Range graph values for case 1 (Line 2)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
325.0	24.7269	72.734	49.1951	15.553
335.0	24.7041	72.6779	49.1465	15.5438
345.0	24.6605	72.6212	49.0978	15.5347
355.0	24.6261	72.564	49.0495	15.5254
365.0	24.6019	72.5064	49.0013	15.5157
375.0	24.5807	72.4483	48.9529	15.5062
385.0	24.5371	72.39	48.9052	15.496
395.0	24.5	72.3314	48.8575	15.4856
405.0	24.4731	72.2725	48.8095	15.4751
415.0	24.455	72.2134	48.7611	15.4648
425.0	24.4303	72.1541	48.7127	15.4544
435.0	24.3934	72.0946	48.6647	15.4438
445.0	24.3654	72.0348	48.6171	15.4329
455.0	24.3465	71.9749	48.5695	15.422
465.0	24.334	71.9149	48.5219	15.4109
475.0	24.3149	71.8548	48.4743	15.3996
485.0	24.2851	71.7948	48.4268	15.3883
495.0	24.2638	71.7347	48.3803	15.376
505.0	24.2497	71.6743	48.3336	15.3633
515.0	24.2401	71.6137	48.287	15.3504
525.0	24.2123	71.5526	48.2399	15.3376
535.0	24.1865	71.4911	48.1916	15.3252
545.0	24.1687	71.4291	48.1446	15.312
555.0	24.1569	71.3665	48.0975	15.2987
565.0	24.1428	71.3034	48.0511	15.285
575.0	24.1164	71.2397	48.0032	15.2719
585.0	24.0975	71.1755	47.9558	15.2587
595.0	24.0845	71.1108	47.9099	15.2444
602.5	19.7074	69.9959	46.8606	15.4002
607.5	0.0	80.5276	44.8235	16.2843
612.5	0.0	90.7054	42.8671	16.6263
617.5	0.0	91.8482	40.8491	16.6993
622.5	0.0	91.5641	38.8765	16.7032
627.5	0.0	91.3646	36.9893	16.5889
632.5	0.0	90.5595	35.1858	16.5061
637.5	0.0	88.788	33.4101	16.435
642.5	0.0	89.1658	31.7257	16.3594
647.5	0.0	88.8927	30.1703	16.3679
652.5	0.0	89.1159	28.6549	16.3375
657.5	0.0	88.8218	27.2156	16.3423
662.5	0.0	89.3861	25.9235	16.4171
667.5	0.0	91.6489	24.7795	16.5772
672.5	0.0	103.2113	24.0441	17.542
677.5	0.0	116.9461	22.8708	17.7091
682.5	0.0	114.294	21.747	17.0951
687.5	0.0	104.1595	21.3	16.75

Appendix 2A: Range graph values for case 1 (Line 2)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
692.5	0.0	97.7144	20.9671	16.3514
697.5	0.0	95.1174	20.7914	16.0007
702.5	0.0	93.2505	20.7293	15.6124
707.5	0.0	92.8224	20.8339	15.1456
712.5	0.0	92.5178	21.0526	14.6379
717.5	0.0	92.3775	21.2814	14.1612
722.5	0.0	92.4289	21.5052	13.7299
727.5	0.3733	92.215	21.7668	13.3303
732.5	0.0	92.3081	22.0337	12.9479
737.5	0.0	92.1724	22.293	12.5903
742.5	0.0	92.1054	22.4963	12.2523
747.5	0.0	91.9732	22.7115	11.9515
752.5	0.0	91.872	22.922	11.6674
757.5	0.0806	91.7581	23.0854	11.3724
762.5	0.251	91.7558	23.2915	11.1162
767.5	0.5834	91.8259	23.4463	10.905
772.5	0.7514	92.0284	23.5417	10.7217
777.5	0.4605	91.5482	23.5834	10.5412
782.5	0.1426	90.7264	23.5583	10.3637
787.5	0.0	89.6616	23.4652	10.1848
792.5	0.0	88.7864	23.3027	10.0723
797.5	0.0	87.7694	22.9847	9.8791
802.5	0.2125	86.8201	22.6291	9.676
807.5	0.1825	85.8589	22.2788	9.4883
812.5	0.0	84.8312	21.935	9.311
817.5	0.0	83.9135	21.5965	9.1592
822.5	0.0	82.8335	21.2613	9.0102
827.5	0.0	81.9235	20.9279	8.8726
832.5	0.0	80.922	20.6054	8.7451
837.5	0.0	79.9534	20.2833	8.6289
842.5	0.0	79.0381	19.9621	8.4675
847.5	0.0	78.0066	19.6468	8.2847
852.5	0.0	77.1849	19.3604	8.1686
857.5	0.0	76.241	19.0841	8.0538
862.5	0.0	75.3504	18.8471	7.9519
867.5	0.0	74.5185	18.6375	7.8671
872.5	0.0	73.7866	18.4754	7.8421
877.5	0.0	76.8783	18.3797	7.9796
882.5	0.0	90.0797	18.3612	8.4238
887.5	0.0	104.499	18.3837	8.9886
892.5	0.0	116.4211	18.4258	9.5214
897.5	0.0	123.309	18.4708	9.8547
900.0	0.031	123.3411	18.5026	9.8544

Appendix 2A: Range graph values for case 1 (Line 3)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
0.0	78.1824	126.5594	103.6839	16.0787
2.5	77.0332	124.1458	102.0012	15.6461
7.5	85.8442	125.3244	106.9065	13.0682
12.5	83.5136	123.3568	104.755	13.1967
17.5	81.2026	121.3842	102.6064	13.3205
22.5	78.8965	119.4075	100.4607	13.4385
27.5	76.6109	117.4384	98.3182	13.5503
32.5	74.3501	115.4702	96.1793	13.6557
37.5	72.1029	113.4983	94.0443	13.7556
42.5	69.8624	111.5239	91.9144	13.8504
47.5	67.6437	109.548	89.7902	13.9412
52.5	65.3818	107.5721	87.6723	14.0294
57.5	63.1273	105.5992	85.562	14.1157
62.5	60.8918	103.6326	83.4605	14.2005
67.5	58.6743	101.6753	81.3686	14.2858
72.5	56.4737	99.7303	79.2881	14.3715
77.5	54.2749	97.8003	77.2198	14.4589
82.5	52.0817	95.891	75.1655	14.5483
87.5	49.905	94.0035	73.1265	14.6404
92.5	47.7455	92.138	71.1049	14.735
97.5	45.5785	90.2978	69.1024	14.8323
105.0	44.4581	89.3685	68.0857	14.8835
115.0	44.4075	89.3271	68.0392	14.8833
125.0	44.3579	89.2856	67.9928	14.883
135.0	44.309	89.2441	67.9465	14.8825
145.0	44.2608	89.2026	67.9003	14.882
155.0	44.2139	89.1613	67.8541	14.8814
165.0	44.1615	89.1201	67.808	14.8808
175.0	44.0904	89.079	67.7619	14.8802
185.0	44.0217	89.0379	67.7159	14.8796
195.0	43.9558	88.9969	67.6701	14.8789
205.0	43.8927	88.9558	67.6243	14.878
215.0	43.8323	88.9147	67.5786	14.8771
225.0	43.7744	88.8736	67.533	14.8761
235.0	43.7192	88.8323	67.4874	14.8751
245.0	43.667	88.7908	67.4419	14.8739
255.0	43.6182	88.7491	67.3965	14.8727
265.0	43.5729	88.7072	67.3512	14.8712
275.0	43.5306	88.6649	67.3059	14.8699
285.0	43.49	88.6224	67.2606	14.8683
295.0	43.4484	88.5795	67.2155	14.8666
305.0	43.4034	88.5363	67.1703	14.8649
315.0	43.3538	88.4927	67.1253	14.8629
325.0	43.3001	88.4488	67.0802	14.8609

Appendix 2A: Range graph values for case 1 (Line 3)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
335.0	43.2454	88.4045	67.0353	14.8586
345.0	43.1928	88.3599	66.9904	14.8562
355.0	43.1435	88.315	66.9457	14.8536
365.0	43.098	88.2697	66.9009	14.8508
375.0	43.0561	88.2241	66.8563	14.8477
385.0	43.0172	88.1782	66.8118	14.8444
395.0	42.9806	88.132	66.7672	14.8411
405.0	42.9429	88.0854	66.7226	14.8376
415.0	42.8985	88.0387	66.6781	14.8339
425.0	42.8566	87.9916	66.6336	14.8302
435.0	42.8172	87.9443	66.5892	14.826
445.0	42.7801	87.8967	66.5449	14.8217
455.0	42.7445	87.8489	66.5006	14.8171
465.0	42.7101	87.8008	66.4565	14.8122
475.0	42.6772	87.7524	66.4124	14.807
485.0	42.6468	87.7037	66.3684	14.8015
495.0	42.6203	87.6548	66.3245	14.7958
505.0	42.598	87.6057	66.2804	14.7901
515.0	42.5794	87.5562	66.2364	14.7841
525.0	42.5646	87.5065	66.1924	14.7779
535.0	42.5395	87.4565	66.1486	14.7713
545.0	42.4991	87.4062	66.1047	14.7646
555.0	42.4613	87.3556	66.0609	14.7576
565.0	42.4254	87.3046	66.0171	14.7504
575.0	42.3908	87.2534	65.9734	14.7429
585.0	42.3574	87.2018	65.9299	14.7348
595.0	42.3258	87.1499	65.8865	14.7265
602.5	41.2502	86.1113	64.8602	14.7024
607.5	38.299	84.1067	62.8636	14.6739
612.5	35.5115	82.1289	60.8892	14.6531
617.5	32.8864	80.1804	58.9431	14.6346
622.5	30.4168	78.2647	57.0277	14.619
627.5	28.0838	76.3864	55.1584	14.5896
632.5	25.8866	74.5493	53.322	14.5714
637.5	23.8154	72.7582	51.5257	14.5602
642.5	21.8591	71.0249	49.7778	14.5513
647.5	20.0062	69.3475	48.084	14.5457
652.5	18.2528	67.7316	46.4326	14.5692
657.5	16.5914	66.1833	44.8656	14.5715
662.5	15.0181	64.7104	43.354	14.6053
667.5	13.5194	63.3212	41.9271	14.6406
672.5	12.0872	62.0223	40.584	14.6899
677.5	10.7226	60.8184	39.3251	14.7648

Appendix 2A: Range graph values for case 1 (Line 3)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
682.5	9.4327	59.7145	38.18	14.8316
687.5	8.2268	58.7182	37.1477	14.9033
692.5	7.1196	57.8345	36.2359	14.9767
697.5	6.1417	57.0609	35.4794	15.0073
702.5	5.3605	56.3902	34.8758	15.0023
707.5	5.6813	55.824	34.4272	14.9483
712.5	6.1555	55.3769	34.1048	14.8327
717.5	6.5943	55.0457	33.8388	14.7091
722.5	7.1948	54.8331	33.6715	14.5217
727.5	7.9683	54.7259	33.6296	14.2243
732.5	8.932	54.5702	33.7634	13.7846
737.5	9.8142	54.2307	33.9784	13.327
742.5	10.6681	53.9192	34.2036	12.9222
747.5	11.4953	53.6515	34.4438	12.5395
752.5	12.3009	53.4236	34.6957	12.173
757.5	13.0825	53.2316	34.958	11.8191
762.5	13.8406	53.0663	35.2249	11.4823
767.5	14.5773	52.9219	35.4709	11.1751
772.5	15.2944	52.7957	35.6711	10.9141
777.5	15.9968	52.6861	35.877	10.666
782.5	16.6929	52.5916	36.0816	10.4351
787.5	17.1149	52.5106	36.2763	10.2168
792.5	16.9833	52.4413	36.4278	10.0346
797.5	16.8019	52.3834	36.5029	9.8807
802.5	16.5617	52.334	36.4784	9.7549
807.5	16.264	52.2909	36.3051	9.646
812.5	15.9114	52.2535	35.9215	9.532
817.5	15.5319	51.6531	35.2508	9.3585
822.5	15.188	50.5848	34.4649	9.1507
827.5	14.8784	49.4564	33.687	8.9433
832.5	14.491	48.3858	32.9644	8.7499
837.5	14.0596	47.4011	32.3004	8.5722
842.5	13.6667	46.5005	31.6937	8.4104
847.5	13.3115	45.6827	31.1423	8.2648
852.5	12.9924	44.9461	30.6469	8.1335
857.5	12.7101	44.2897	30.2046	8.0193
862.5	12.4428	43.7125	29.8219	7.9124
867.5	12.2124	43.2134	29.4899	7.8224
872.5	12.0193	42.7916	29.2139	7.7425
877.5	11.8638	42.4463	28.989	7.6782
882.5	11.7457	42.177	28.8157	7.6263
887.5	11.6649	41.9831	28.6957	7.5852
892.5	11.6222	41.8642	28.6251	7.559
897.5	11.6189	41.8226	28.6086	7.545
900.0	11.6541	41.8561	28.6429	7.5445

Appendix 2A: Range graph values for case 1 (Line 4)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
0.0	63.8257	88.2806	77.1372	6.6765
2.5	62.1032	87.5946	75.9748	6.9929
7.5	61.6389	98.738	80.5956	10.5641
12.5	59.4964	96.4984	78.4282	10.5391
17.5	57.3586	94.2575	76.2653	10.5206
22.5	55.2321	92.0111	74.1023	10.5027
27.5	53.121	89.7543	71.9401	10.4847
32.5	51.0275	87.4867	69.779	10.4666
37.5	48.9527	85.3456	67.6201	10.4476
42.5	46.8968	83.2236	65.4644	10.4286
47.5	44.8598	81.098	63.3129	10.4106
52.5	42.7646	78.9687	61.1667	10.394
57.5	40.6146	76.8369	59.0272	10.3804
62.5	38.4318	74.7098	56.9095	10.3819
67.5	36.2581	72.6003	54.7981	10.3845
72.5	34.101	70.5038	52.6971	10.391
77.5	31.9634	68.4275	50.6009	10.3952
82.5	29.8436	66.3899	48.5145	10.3999
87.5	27.7483	64.3826	46.4519	10.4137
92.5	25.6834	62.4197	44.415	10.4349
97.5	23.6504	60.5509	42.4011	10.4612
105.0	22.6268	59.5995	41.3844	10.473
115.0	22.596	59.5419	41.3333	10.4634
125.0	22.5667	59.4826	41.2809	10.4517
135.0	22.5398	59.4217	41.2287	10.4396
145.0	22.5169	59.3595	41.1748	10.4267
155.0	22.4989	59.2961	41.1182	10.4125
165.0	22.485	59.2316	41.0638	10.3989
175.0	22.474	59.1662	41.0114	10.3853
185.0	22.4635	59.0999	40.9586	10.3714
195.0	22.4534	59.0329	40.906	10.3575
205.0	22.4452	58.9652	40.8549	10.3434
215.0	22.4393	58.897	40.8041	10.3295
225.0	22.4361	58.8282	40.7605	10.3181
235.0	22.4353	58.759	40.7068	10.3024
245.0	22.4343	58.6895	40.6499	10.2849
255.0	22.4325	58.6196	40.5934	10.2681
265.0	22.4327	58.5494	40.5412	10.2544
275.0	22.4363	58.4789	40.4856	10.2386
285.0	22.4417	58.4082	40.4308	10.2228
295.0	22.437	58.3374	40.3771	10.2073
305.0	22.4302	58.2664	40.3227	10.1916
315.0	22.425	58.1954	40.2777	10.1794
325.0	22.4222	58.1246	40.2236	10.1614

Appendix 2A: Range graph values for case 1 (Line 4)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
335.0	22.4208	58.0541	40.178	10.1473
345.0	22.4191	57.9842	40.1275	10.1315
355.0	22.4179	57.9148	40.0736	10.1138
365.0	22.419	57.8457	40.0194	10.0962
375.0	22.4228	57.7769	39.9663	10.0803
385.0	22.4274	57.708	39.9108	10.0632
395.0	22.4283	57.6391	39.8584	10.0476
405.0	22.427	57.57	39.8052	10.0316
415.0	22.4261	57.5007	39.7542	10.0157
425.0	22.4248	57.4312	39.7035	9.9992
435.0	22.4215	57.3615	39.6509	9.981
445.0	22.4186	57.2915	39.5995	9.9623
455.0	22.4178	57.2211	39.561	9.9483
465.0	22.4186	57.1504	39.5094	9.9294
475.0	22.4192	57.0793	39.4558	9.9104
485.0	22.4193	57.0077	39.4017	9.8922
495.0	22.4209	56.9358	39.3497	9.8749
505.0	22.4253	56.8634	39.3003	9.8577
515.0	22.4297	56.7907	39.2507	9.8407
525.0	22.4296	56.7176	39.1986	9.8228
535.0	22.4303	56.6442	39.1495	9.8049
545.0	22.4332	56.5704	39.0928	9.7837
555.0	22.4337	56.4961	39.0486	9.765
565.0	22.4338	56.4214	39.0005	9.7444
575.0	22.4341	56.3462	38.9573	9.7254
585.0	22.4365	56.2704	38.9104	9.7063
595.0	22.4416	56.194	38.8641	9.6911
602.5	9.221	84.3809	37.9346	12.2519
607.5	0.0	144.9868	36.6522	17.9153
612.5	0.0	170.7239	34.8102	19.6253
617.5	0.0	174.268	32.9644	20.453
622.5	0.0	176.2786	31.0695	20.5961
627.5	0.0	177.8241	29.2027	20.6083
632.5	0.0	173.7447	27.6476	21.7441
637.5	0.0	178.6497	26.0788	22.9953
642.5	0.0	184.3485	24.4087	23.778
647.5	0.0	189.8747	22.7672	24.3892
652.5	0.0	195.0839	21.2308	25.1487
657.5	0.0	197.3187	19.8709	26.1496
662.5	0.0	203.9704	18.7166	27.6504
667.5	0.0	216.2528	18.5406	32.2534
672.5	0.0	252.5302	17.256	36.7123
677.5	0.0	286.0324	14.5976	33.5703

Appendix 2A: Range graph values for case 1 (Line 4)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
682.5	0.0	238.077	11.7714	21.7404
687.5	0.0	224.9193	11.3713	20.2463
692.5	0.0	216.8165	11.1399	19.3072
697.5	0.0	209.2042	11.1747	18.7772
702.5	0.0	203.8396	11.1617	18.419
707.5	0.0	200.4877	11.0607	18.1041
712.5	0.0	196.0414	11.1788	17.8557
717.5	0.0	193.5502	11.4807	17.7616
722.5	0.0	190.5291	11.8654	17.8482
727.5	0.0	188.1743	12.2737	17.8846
732.5	0.0	185.9681	12.7536	17.9906
737.5	0.0	183.8486	13.2961	18.1413
742.5	0.0	182.0064	13.8453	18.1294
747.5	0.0	180.266	14.4586	18.1415
752.5	0.0	178.8109	15.1384	18.2531
757.5	0.0	177.4842	15.7738	18.0446
762.5	0.0	175.9235	16.3044	17.4898
767.5	0.0	174.6748	16.732	16.7736
772.5	0.0	172.6269	17.1183	16.2863
777.5	0.0	171.3459	17.4939	16.1777
782.5	0.0	169.4471	17.8229	16.0989
787.5	0.0	168.1169	18.116	16.035
792.5	0.0	166.5259	18.4001	15.9663
797.5	0.1469	164.9738	18.6716	15.8776
802.5	0.3493	163.6293	18.931	15.773
807.5	0.0	161.8833	19.179	15.6527
812.5	0.0	160.7632	19.4557	15.5431
817.5	0.0	159.2141	19.7554	15.3926
822.5	0.0	157.9761	20.0239	15.0517
827.5	0.0	156.7144	20.216	14.3181
832.5	0.0	155.3169	20.483	13.8648
837.5	0.0	154.3901	20.915	13.8684
842.5	0.0	153.2361	21.3591	13.8698
847.5	0.1599	152.6147	21.8599	13.9202
852.5	0.1404	152.0004	22.3898	13.9871
857.5	0.1212	152.368	22.9402	14.0854
862.5	0.0	156.2346	23.5262	14.3176
867.5	0.0	166.5873	24.1234	14.8891
872.5	0.0	175.5682	24.6618	15.8098
877.5	0.0	175.3524	25.0271	16.5196
882.5	0.0	183.8737	25.1764	17.0144
887.5	0.0	202.8739	25.2503	18.7346
892.5	0.0	227.4294	25.3733	20.5379
897.5	0.0	244.2268	25.4578	21.6248
900.0	-0.0013	244.2263	25.4575	21.6247

Appendix 2A: Range graph values for case 1 (Line 5)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
0.0	68.7187	102.1013	85.6586	10.4549
2.5	67.3355	100.8011	84.4202	10.4804
7.5	70.8221	107.7819	89.5287	11.6061
12.5	68.5339	105.6272	87.3835	11.6748
17.5	66.2529	103.4941	85.2393	11.7433
22.5	63.9846	101.3586	83.0972	11.8107
27.5	61.7186	99.2341	80.9574	11.8762
32.5	59.4683	97.1037	78.8207	11.9397
37.5	57.2379	94.9733	76.6879	12.0014
42.5	55.0278	92.8504	74.5593	12.0624
47.5	52.8381	90.7274	72.4361	12.1232
52.5	50.6682	88.6062	70.3194	12.184
57.5	48.5176	86.4953	68.2105	12.2458
62.5	46.3861	84.4015	66.1104	12.3097
67.5	44.273	82.3201	64.0201	12.3764
72.5	42.1789	80.271	61.9411	12.4462
77.5	40.104	78.2664	59.8762	12.5198
82.5	38.0494	76.3037	57.8269	12.5973
87.5	35.8771	74.3708	55.7951	12.6789
92.5	33.6543	72.4637	53.7835	12.7642
97.5	31.4557	70.5876	51.7949	12.8526
105.0	30.3374	69.6364	50.7838	12.8977
115.0	30.2878	69.5828	50.7337	12.8954
125.0	30.241	69.5283	50.6837	12.8927
135.0	30.184	69.4728	50.6336	12.8896
145.0	30.1291	69.4165	50.5835	12.886
155.0	30.0798	69.3595	50.5329	12.8825
165.0	30.0353	69.3018	50.4819	12.8787
175.0	29.9893	69.2435	50.4313	12.8744
185.0	29.9382	69.1847	50.3806	12.8699
195.0	29.8904	69.1253	50.3296	12.8651
205.0	29.8489	69.0654	50.279	12.8602
215.0	29.814	69.0051	50.2291	12.855
225.0	29.7829	68.9445	50.1791	12.8499
235.0	29.7474	68.8834	50.1294	12.8451
245.0	29.7069	68.8219	50.0799	12.8401
255.0	29.6682	68.7601	50.0304	12.8351
265.0	29.6319	68.6979	49.9801	12.8301
275.0	29.5915	68.6354	49.9297	12.825
285.0	29.544	68.5726	49.8796	12.8195
295.0	29.4984	68.5095	49.8293	12.8138
305.0	29.4583	68.4461	49.7789	12.808
315.0	29.423	68.3825	49.7284	12.8021
325.0	29.3872	68.3187	49.6788	12.7958

Appendix 2A: Range graph values for case 1 (Line 5)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
335.0	29.3466	68.2547	49.6294	12.7894
345.0	29.3076	68.1904	49.5805	12.7828
355.0	29.2746	68.1259	49.5321	12.7762
365.0	29.2475	68.0613	49.4831	12.7697
375.0	29.2234	67.9964	49.4333	12.7635
385.0	29.1948	67.9312	49.3833	12.7573
395.0	29.1577	67.8658	49.3336	12.7506
405.0	29.117	67.8001	49.2843	12.7435
415.0	29.0763	67.7342	49.2348	12.7363
425.0	29.0367	67.668	49.1854	12.7286
435.0	28.9986	67.6017	49.1346	12.7213
445.0	28.9628	67.5351	49.0847	12.7135
455.0	28.9294	67.4685	49.0363	12.7051
465.0	28.8976	67.4017	48.9887	12.6963
475.0	28.8661	67.335	48.9401	12.6881
485.0	28.8346	67.2681	48.8903	12.6802
495.0	28.8044	67.2013	48.8403	12.6723
505.0	28.7792	67.1344	48.7908	12.664
515.0	28.761	67.0674	48.7421	12.6551
525.0	28.7367	67.0	48.6958	12.6446
535.0	28.7086	66.9323	48.6482	12.6346
545.0	28.6864	66.8641	48.5976	12.625
555.0	28.673	66.7955	48.5501	12.6146
565.0	28.6326	66.7266	48.5015	12.6041
575.0	28.6	66.6572	48.4524	12.5935
585.0	28.5779	66.5873	48.4035	12.5831
595.0	28.556	66.5169	48.3537	12.5722
602.5	25.4662	65.3675	47.3466	12.7524
607.5	5.0423	86.4571	45.384	13.8039
612.5	0.0	98.7444	43.4285	14.331
617.5	0.0	100.9985	41.3918	14.466
622.5	0.0	99.8856	39.3425	14.5623
627.5	0.0	98.8528	37.3898	14.3894
632.5	0.0	92.9888	35.4499	14.303
637.5	0.0	83.1957	33.5363	14.3146
642.5	0.0	80.5921	31.6979	14.2722
647.5	0.0	81.7893	29.915	14.2388
652.5	0.0	81.2593	28.2102	14.1726
657.5	0.0	80.7524	26.5842	14.1978
662.5	0.0	80.9334	25.0491	14.2565
667.5	0.0	82.1691	23.6208	14.3996
672.5	0.0	82.6509	22.3154	14.5954
677.5	0.0	86.1706	21.2356	15.0242

Appendix 2A: Range graph values for case 1 (Line 5)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
682.5	0.0	110.5375	20.8073	17.3972
687.5	0.0	119.3636	19.1082	16.223
692.5	0.0	117.8293	18.1269	15.1149
697.5	0.0	104.6756	17.9001	15.01
702.5	0.0	98.7958	17.4759	14.1707
707.5	0.0	96.4374	17.3831	13.816
712.5	0.0	94.4654	17.462	13.3671
717.5	0.0	93.1219	17.8368	12.8761
722.5	0.0	92.9529	18.1227	12.4253
727.5	0.2175	92.3092	18.4091	12.0347
732.5	0.9405	91.8992	18.701	11.6619
737.5	1.4545	91.6137	18.9979	11.3168
742.5	1.5444	91.2653	19.264	10.9646
747.5	2.088	91.3281	19.3895	10.696
752.5	1.6849	91.4288	19.2874	10.4561
757.5	1.1262	91.1173	18.882	10.194
762.5	0.5297	90.2346	18.408	9.9641
767.5	0.0	89.1066	17.9435	9.7503
772.5	0.0	88.1818	17.4622	9.4921
777.5	0.0	87.0842	17.0164	9.2907
782.5	0.0	86.0929	16.5802	9.0807
787.5	0.0	85.0396	16.1535	8.8504
792.5	0.0425	83.9636	15.7527	8.655
797.5	0.4142	82.9492	15.3557	8.4549
802.5	0.2082	81.7597	14.9766	8.2959
807.5	0.0	80.7901	14.6062	8.13
812.5	0.0	79.6413	14.2301	7.9403
817.5	0.1381	78.644	13.8869	7.7945
822.5	0.0973	77.5958	13.5891	7.7223
827.5	0.0	76.5185	13.2653	7.5437
832.5	0.0	75.571	12.9798	7.4133
837.5	0.0	74.4648	12.7053	7.2543
842.5	0.0	73.5536	12.4715	7.129
847.5	0.0	72.5494	12.2303	6.9382
852.5	0.0	71.54	12.0312	6.8364
857.5	0.0	70.6335	11.8534	6.7376
862.5	0.0	69.5777	11.6976	6.6449
867.5	0.0	68.6992	11.5645	6.5701
872.5	0.0	67.8483	11.4633	6.5247
877.5	0.0	67.7438	11.389	6.5451
882.5	0.0	77.7483	11.3809	6.9768
887.5	0.0	93.0037	11.4351	7.7589
892.5	0.0	106.3859	11.5064	8.5777
897.5	0.0	114.2189	11.56	9.0941
900.0	0.0238	114.2437	11.5846	9.0939

Appendix 2A: Range graph values for case 1 (Line 6)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
0.0	90.0183	130.2452	112.1814	13.59
2.5	88.7769	129.2233	111.0242	13.6651
7.5	88.8973	130.5116	111.624	14.1691
12.5	86.4872	128.4961	109.3715	14.3181
17.5	84.0673	126.495	107.1233	14.4664
22.5	81.6585	124.4982	104.8797	14.6125
27.5	79.2687	122.5042	102.641	14.7554
32.5	76.8999	120.5146	100.4073	14.8956
37.5	74.496	118.5328	98.1793	15.0328
42.5	72.1103	116.5583	95.9571	15.1682
47.5	69.7427	114.5918	93.7421	15.3017
52.5	67.3934	112.6351	91.5346	15.4344
57.5	65.0587	110.6908	89.3354	15.5672
62.5	62.7373	108.7579	87.1457	15.7007
67.5	60.4263	106.8371	84.9663	15.8354
72.5	58.1042	104.93	82.7986	15.9722
77.5	55.7951	103.0389	80.6436	16.1115
82.5	53.4618	101.1644	78.5026	16.2535
87.5	51.1235	99.3087	76.3772	16.3987
92.5	48.7547	97.4742	74.2691	16.547
97.5	46.4037	95.6631	72.18	16.698
105.0	45.2121	94.7572	71.1248	16.777
115.0	45.169	94.7315	71.0858	16.7792
125.0	45.1302	94.7058	71.047	16.7811
135.0	45.0931	94.68	71.0083	16.7828
145.0	45.0566	94.654	70.9698	16.7843
155.0	45.0212	94.6278	70.9313	16.7856
165.0	44.987	94.6013	70.893	16.7867
175.0	44.9458	94.5747	70.8547	16.7876
185.0	44.9066	94.5477	70.8165	16.7884
195.0	44.8694	94.5205	70.7784	16.7891
205.0	44.8334	94.493	70.7403	16.7896
215.0	44.7978	94.4652	70.7023	16.7899
225.0	44.7628	94.437	70.6643	16.7901
235.0	44.7289	94.4086	70.6263	16.7901
245.0	44.6962	94.3798	70.5883	16.7901
255.0	44.6649	94.3508	70.5503	16.7898
265.0	44.6352	94.3214	70.5124	16.7894
275.0	44.6069	94.2917	70.4745	16.7888
285.0	44.5798	94.2618	70.4367	16.788
295.0	44.553	94.2315	70.3989	16.7869
305.0	44.5258	94.201	70.3612	16.7857
315.0	44.499	94.1702	70.3235	16.7842
325.0	44.4724	94.1392	70.2858	16.7826

Appendix 2A: Range graph values for case 1 (Line 6)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
335.0	44.445	94.1078	70.2481	16.7808
345.0	44.4109	94.0762	70.2104	16.7788
355.0	44.3749	94.0443	70.1728	16.7766
365.0	44.3401	94.0121	70.1352	16.7742
375.0	44.3068	93.9797	70.0977	16.7716
385.0	44.2751	93.9469	70.0602	16.7687
395.0	44.2452	93.9138	70.0228	16.7656
405.0	44.2169	93.8803	69.9855	16.7622
415.0	44.1904	93.8464	69.9482	16.7585
425.0	44.1654	93.812	69.911	16.7546
435.0	44.1419	93.7773	69.8739	16.7503
445.0	44.1195	93.7421	69.8369	16.7458
455.0	44.0982	93.7066	69.7999	16.7411
465.0	44.0775	93.6705	69.7629	16.7361
475.0	44.0573	93.6341	69.7261	16.7309
485.0	44.0374	93.5972	69.6893	16.7254
495.0	44.0179	93.5599	69.6526	16.7195
505.0	43.9989	93.5222	69.616	16.7134
515.0	43.9807	93.484	69.5795	16.707
525.0	43.9633	93.4454	69.5432	16.7002
535.0	43.9462	93.4064	69.507	16.6931
545.0	43.9219	93.367	69.4711	16.6856
555.0	43.8995	93.3271	69.4352	16.6778
565.0	43.8788	93.287	69.3995	16.6697
575.0	43.8592	93.2465	69.3638	16.6614
585.0	43.8398	93.2057	69.3283	16.6529
595.0	43.8201	93.1648	69.2929	16.6442
602.5	42.7266	92.1991	68.3308	16.6183
607.5	40.5005	90.3436	66.469	16.5827
612.5	38.3599	88.5271	64.6425	16.5539
617.5	36.307	86.7547	62.8557	16.5312
622.5	34.3446	85.0309	61.1135	16.5139
627.5	32.4754	83.3602	59.4206	16.5025
632.5	30.6981	81.7577	57.782	16.4974
637.5	29.0108	80.2313	56.203	16.4994
642.5	27.4136	78.7731	54.6889	16.5094
647.5	25.9033	77.3876	53.2445	16.5294
652.5	24.4787	76.08	51.8773	16.5574
657.5	23.1404	74.8561	50.5929	16.5936
662.5	21.8858	73.7205	49.3975	16.6372
667.5	20.7144	72.6765	48.2978	16.6861
672.5	19.6258	71.7246	47.3004	16.7368
677.5	18.623	70.8657	46.4109	16.7853

Appendix 2A: Range graph values for case 1 (Line 6)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
682.5	17.7138	70.1033	45.6375	16.8227
687.5	16.9158	69.4402	44.985	16.8421
692.5	16.2654	68.8723	44.4616	16.8312
697.5	15.8292	68.3905	44.0536	16.806
702.5	15.953	67.99	43.7212	16.767
707.5	16.2226	67.6985	43.4417	16.7012
712.5	16.6276	67.499	43.2468	16.5564
717.5	17.2186	67.3804	43.1521	16.3107
722.5	18.0271	67.3519	43.1871	15.9354
727.5	19.1514	66.8201	43.4425	15.397
732.5	20.1766	66.3677	43.7551	14.8974
737.5	21.1864	66.2637	44.0382	14.505
742.5	22.1765	66.1981	44.329	14.1498
747.5	23.1647	66.1483	44.6325	13.8161
752.5	24.1375	66.1093	44.9405	13.5029
757.5	24.505	66.0742	45.1914	13.2191
762.5	24.5568	66.0138	45.3422	12.9486
767.5	23.7479	65.319	45.263	12.6734
772.5	22.9834	64.2773	44.7365	12.3531
777.5	22.2617	63.1474	44.1371	12.0434
782.5	21.5816	62.0137	43.5132	11.7462
787.5	20.9416	60.8794	42.8662	11.461
792.5	20.3406	59.7448	42.1962	11.1877
797.5	19.7773	58.6099	41.5044	10.9244
802.5	19.2506	57.4746	40.7913	10.6705
807.5	18.7597	56.339	40.0574	10.425
812.5	18.3033	55.203	39.3035	10.1875
817.5	17.8807	54.0667	38.5305	9.957
822.5	17.4911	52.9299	37.7382	9.7345
827.5	17.1324	51.7928	36.9362	9.5148
832.5	16.7766	50.6942	36.1638	9.3049
837.5	16.4532	49.6856	35.4555	9.1119
842.5	16.1615	48.7653	34.811	8.9345
847.5	15.9007	47.9315	34.229	8.7724
852.5	15.6701	47.1828	33.7083	8.6257
857.5	15.4691	46.5178	33.2476	8.4943
862.5	15.2973	45.9355	32.845	8.3792
867.5	15.1545	45.4347	32.5016	8.2783
872.5	15.0407	45.0147	32.2164	8.1918
877.5	14.9556	44.6748	31.9892	8.1193
882.5	14.8991	44.4144	31.8178	8.0623
887.5	14.8711	44.233	31.7045	8.0184
892.5	14.8717	44.1304	31.6467	7.9897
897.5	14.9019	44.109	31.6477	7.9754
900.0	14.9491	44.1544	31.6939	7.9749

Appendix 2A: Range graph values for case 1 (Line 7)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
0.0	78.4935	112.0012	97.0656	10.6056
2.5	77.286	110.9859	95.8995	10.6523
7.5	75.4116	119.0166	99.183	14.4256
12.5	73.0132	116.9786	96.9663	14.546
17.5	70.6127	114.9461	94.7499	14.6712
22.5	68.2164	112.917	92.5347	14.7984
27.5	65.829	110.9098	90.3209	14.9269
32.5	63.4539	108.9431	88.1094	15.0558
37.5	61.0934	106.9804	85.901	15.1845
42.5	58.7488	105.031	83.6962	15.3137
47.5	56.4208	103.0879	81.4956	15.4441
52.5	54.1093	101.1539	79.3002	15.5755
57.5	51.8138	99.2262	77.1114	15.7078
62.5	49.5337	97.309	74.9294	15.8429
67.5	47.2691	95.4112	72.7563	15.9797
72.5	44.9011	93.5293	70.5919	16.1203
77.5	42.503	91.6638	68.4381	16.2641
82.5	40.1191	89.8256	66.2968	16.4106
87.5	37.7523	88.0096	64.1685	16.5615
92.5	35.406	86.2166	62.0557	16.7153
97.5	33.0841	84.4461	59.9599	16.8724
105.0	31.9116	83.5544	58.8975	16.9516
115.0	31.8714	83.5229	58.853	16.9507
125.0	31.8337	83.4905	58.8085	16.9493
135.0	31.7997	83.4571	58.7641	16.9474
145.0	31.7653	83.4227	58.7198	16.9453
155.0	31.7311	83.3876	58.6756	16.9428
165.0	31.7023	83.3519	58.6316	16.94
175.0	31.6808	83.3156	58.5877	16.9369
185.0	31.6651	83.2787	58.5439	16.9337
195.0	31.652	83.2415	58.5002	16.9303
205.0	31.6411	83.2038	58.4567	16.9267
215.0	31.6321	83.1659	58.4132	16.9229
225.0	31.6209	83.1276	58.3698	16.9191
235.0	31.5875	83.0891	58.3265	16.9151
245.0	31.5414	83.0503	58.2832	16.9111
255.0	31.4972	83.0112	58.2401	16.907
265.0	31.4552	82.9719	58.197	16.9027
275.0	31.4165	82.9323	58.1539	16.8985
285.0	31.3808	82.8924	58.111	16.8939
295.0	31.3481	82.8521	58.0682	16.8893
305.0	31.3198	82.8115	58.0256	16.8843
315.0	31.2961	82.7705	57.983	16.8794
325.0	31.2743	82.7291	57.9406	16.8743

Appendix 2A: Range graph values for case 1 (Line 7)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
335.0	31.2531	82.6873	57.8982	16.869
345.0	31.2347	82.6452	57.8558	16.8636
355.0	31.2198	82.6026	57.8136	16.858
365.0	31.1691	82.5596	57.7715	16.8524
375.0	31.0955	82.5163	57.7293	16.8466
385.0	31.0231	82.4727	57.6873	16.8405
395.0	30.9532	82.4288	57.6456	16.8341
405.0	30.8888	82.3846	57.6037	16.8278
415.0	30.8314	82.3401	57.562	16.8211
425.0	30.7797	82.2954	57.5204	16.8143
435.0	30.732	82.2505	57.479	16.8071
445.0	30.6896	82.2053	57.4376	16.7998
455.0	30.6394	82.1599	57.3962	16.7924
465.0	30.5903	82.1142	57.355	16.7845
475.0	30.545	82.0683	57.314	16.7764
485.0	30.5043	82.022	57.2728	16.7684
495.0	30.4678	81.9755	57.2316	16.7601
505.0	30.437	81.9286	57.1908	16.7513
515.0	30.4166	81.8815	57.1502	16.7421
525.0	30.4089	81.8341	57.1095	16.7329
535.0	30.4076	81.7864	57.069	16.7234
545.0	30.4013	81.7385	57.0285	16.7136
555.0	30.3852	81.6902	56.9883	16.7035
565.0	30.3587	81.6417	56.9483	16.6928
575.0	30.3231	81.5931	56.9085	16.6819
585.0	30.2811	81.5442	56.8689	16.6707
595.0	30.2364	81.4952	56.829	16.6597
602.5	28.6656	80.4753	55.8244	16.6226
607.5	24.6799	78.5188	53.8678	16.5938
612.5	21.0974	76.6024	51.9367	16.5902
617.5	18.083	74.7306	50.0352	16.6083
622.5	15.6823	72.9097	48.1855	16.622
627.5	13.762	71.1474	46.3936	16.6364
632.5	12.1044	69.4519	44.6637	16.6568
637.5	10.5484	67.8348	42.9983	16.6919
642.5	9.0287	66.3016	41.4166	16.7282
647.5	7.4552	64.8594	39.9161	16.782
652.5	5.9625	63.5177	38.5216	16.8337
657.5	4.5532	62.281	37.2341	16.8969
662.5	3.1972	61.1524	36.0602	16.9731
667.5	1.9622	60.1364	35.0196	17.0416
672.5	0.875	59.2388	34.1335	17.0827
677.5	0.0	58.4579	33.4077	17.0953

Appendix 2A: Range graph values for case 1 (Line 7)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
682.5	0.0	57.7844	32.8603	17.0458
687.5	0.0	57.2265	32.4182	16.9771
692.5	0.5313	56.7779	32.0686	16.8679
697.5	1.2173	56.4471	31.8809	16.6282
702.5	1.9491	56.2357	31.7396	16.36
707.5	2.8246	56.1236	31.7344	15.9727
712.5	3.7234	55.9682	31.8146	15.4972
717.5	4.6244	55.5987	31.9452	15.0217
722.5	5.5126	55.1826	32.0891	14.5869
727.5	6.3756	54.7885	32.241	14.185
732.5	7.2127	54.4338	32.4232	13.7738
737.5	8.023	54.1174	32.6043	13.3903
742.5	8.8049	53.8359	32.8121	12.997
747.5	9.5579	53.5815	33.0246	12.6225
752.5	10.2835	53.3486	33.2402	12.2675
757.5	10.9836	53.1336	33.4547	11.936
762.5	11.6556	52.9343	33.6788	11.6149
767.5	12.291	52.7483	33.9026	11.3134
772.5	12.8864	52.5746	34.1018	11.0477
777.5	13.4466	52.4132	34.3067	10.7914
782.5	13.9798	52.2643	34.5122	10.5484
787.5	14.4999	52.1271	34.7204	10.3124
792.5	15.0372	52.002	34.9477	10.0653
797.5	15.1655	51.89	35.1449	9.853
802.5	15.2871	51.7906	35.3212	9.6687
807.5	15.4533	51.7038	35.4873	9.4948
812.5	15.6522	51.6295	35.6231	9.3245
817.5	15.7237	51.5677	35.6971	9.1797
822.5	15.7733	51.5176	35.7297	9.0366
827.5	15.7651	51.4785	35.7079	8.8817
832.5	15.7909	51.4477	35.6094	8.7336
837.5	15.8953	51.1853	35.4584	8.5529
842.5	16.0746	50.7707	35.3733	8.379
847.5	16.3119	50.4471	35.3455	8.2292
852.5	16.5895	50.2135	35.3895	8.0829
857.5	16.9024	50.0695	35.4904	7.9591
862.5	17.2499	50.0147	35.6583	7.8435
867.5	17.6312	50.0489	35.8896	7.7432
872.5	18.0462	50.1721	36.1885	7.6517
877.5	18.4943	50.3846	36.5516	7.5759
882.5	18.9722	50.6867	36.9835	7.5094
887.5	19.4868	51.0794	37.4808	7.4566
892.5	20.0602	51.5636	38.0449	7.4165
897.5	20.7483	52.2088	38.7323	7.3963
900.0	21.5138	52.9393	39.4806	7.3868

Appendix 2A: Range graph values for case 1 (Line 8)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
0.0	89.5176	138.9461	116.5624	16.5871
2.5	88.505	137.8562	115.4886	16.5486
7.5	93.9482	136.1704	117.1268	14.3081
12.5	91.5158	134.1825	114.8749	14.472
17.5	89.1051	132.1972	112.6285	14.631
22.5	86.6925	130.21	110.3876	14.7836
27.5	84.2796	128.2193	108.1522	14.9294
32.5	81.8948	126.2275	105.9227	15.0684
37.5	79.5382	124.24	103.6994	15.2008
42.5	77.1967	122.2541	101.483	15.3278
47.5	74.8655	120.2694	99.2741	15.4502
52.5	72.5592	118.2877	97.0735	15.5691
57.5	70.2756	116.3115	94.8822	15.6857
62.5	68.01	114.3427	92.7011	15.8008
67.5	65.724	112.3835	90.5316	15.9154
72.5	63.4483	110.4374	88.3747	16.0304
77.5	61.1477	108.5134	86.2318	16.1465
82.5	58.8286	106.6116	84.1041	16.2645
87.5	56.5276	104.7274	81.9933	16.3846
92.5	54.2452	102.8599	79.9012	16.5069
97.5	51.982	101.0103	77.8294	16.6315
105.0	50.8358	100.0825	76.7848	16.6966
115.0	50.795	100.0545	76.7473	16.6975
125.0	50.7546	100.0268	76.71	16.6983
135.0	50.7148	99.9991	76.673	16.6991
145.0	50.6757	99.9714	76.636	16.6999
155.0	50.6371	99.9437	76.5992	16.7006
165.0	50.5994	99.916	76.5624	16.7015
175.0	50.5624	99.888	76.5257	16.7023
185.0	50.5263	99.86	76.489	16.703
195.0	50.4908	99.8317	76.4523	16.7038
205.0	50.4553	99.8032	76.4157	16.7044
215.0	50.4196	99.7745	76.3791	16.7049
225.0	50.3836	99.7456	76.3426	16.7054
235.0	50.3468	99.7164	76.306	16.7057
245.0	50.3069	99.6869	76.2695	16.7059
255.0	50.2659	99.6573	76.2329	16.706
265.0	50.2256	99.6274	76.1963	16.706
275.0	50.1866	99.5973	76.1597	16.7059
285.0	50.1492	99.567	76.1231	16.7056
295.0	50.1136	99.5366	76.0864	16.7053
305.0	50.0798	99.5059	76.0498	16.7046
315.0	50.0478	99.4751	76.0133	16.7038
325.0	50.0174	99.444	75.9767	16.7026

Appendix 2A: Range graph values for case 1 (Line 8)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
335.0	49.9885	99.4128	75.9403	16.7013
345.0	49.9609	99.3814	75.9038	16.6997
355.0	49.9347	99.3498	75.8673	16.6979
365.0	49.9097	99.318	75.8309	16.6959
375.0	49.886	99.286	75.7944	16.6937
385.0	49.8633	99.2537	75.758	16.6912
395.0	49.8345	99.2212	75.7216	16.6886
405.0	49.7961	99.1885	75.6851	16.6858
415.0	49.7605	99.1555	75.6487	16.6826
425.0	49.7287	99.1223	75.6124	16.6792
435.0	49.701	99.0887	75.5761	16.6755
445.0	49.6769	99.0549	75.54	16.6715
455.0	49.6549	99.0207	75.5039	16.6671
465.0	49.6333	98.9862	75.4679	16.6624
475.0	49.6108	98.9513	75.4319	16.6574
485.0	49.5881	98.9161	75.396	16.6521
495.0	49.566	98.8805	75.3602	16.6466
505.0	49.5453	98.8445	75.3245	16.6407
515.0	49.5261	98.8081	75.2888	16.6347
525.0	49.5084	98.7713	75.2531	16.6284
535.0	49.4921	98.7342	75.2175	16.6217
545.0	49.4771	98.6966	75.1821	16.6147
555.0	49.4607	98.6586	75.1469	16.6073
565.0	49.4451	98.6202	75.1119	16.5996
575.0	49.4306	98.5815	75.077	16.5916
585.0	49.4173	98.5425	75.0422	16.5833
595.0	49.4045	98.5031	75.0075	16.5747
602.5	48.4949	97.5509	74.0565	16.5463
607.5	46.4693	95.718	72.2144	16.5052
612.5	44.5013	93.9215	70.4058	16.4697
617.5	42.5962	92.1647	68.6345	16.4394
622.5	40.7608	90.4515	66.9045	16.4139
627.5	38.9975	88.7886	65.2194	16.3939
632.5	37.3053	87.1909	63.5805	16.384
637.5	35.6853	85.6545	61.9961	16.379
642.5	34.1382	84.1806	60.4703	16.3806
647.5	32.6611	82.7722	59.0067	16.3907
652.5	31.2556	81.4337	57.6111	16.4087
657.5	29.9224	80.17	56.2864	16.4371
662.5	28.6623	78.9854	55.0403	16.4732
667.5	27.476	77.8831	53.8793	16.5137
672.5	26.3641	76.8662	52.8065	16.5602
677.5	25.3283	75.939	51.8289	16.607

Appendix 2A: Range graph values for case 1 (Line 8)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
682.5	24.3718	75.1034	50.9511	16.6512
687.5	23.5004	74.3571	50.1824	16.681
692.5	22.7245	73.6957	49.5188	16.7031
697.5	22.0625	73.1185	48.9684	16.7053
702.5	21.5477	72.6297	48.536	16.6786
707.5	21.2301	72.2314	48.1993	16.6403
712.5	21.3319	71.9185	47.9093	16.601
717.5	21.5998	71.6802	47.6726	16.5189
722.5	22.0239	71.5131	47.5214	16.3479
727.5	22.6693	71.4559	47.4834	16.0546
732.5	23.5836	71.405	47.5873	15.6204
737.5	24.7108	70.5748	47.9142	15.0557
742.5	25.7537	70.4009	48.2634	14.5967
747.5	26.7813	70.3256	48.6156	14.1905
752.5	27.7978	70.2692	48.9237	13.8457
757.5	28.7934	70.2237	49.234	13.5257
762.5	29.7861	70.1857	49.5486	13.2217
767.5	29.9606	70.1522	49.8626	12.9404
772.5	29.0893	70.0525	50.1176	12.6916
777.5	28.2036	69.7197	50.2571	12.4708
782.5	27.3292	68.7933	49.9905	12.2282
787.5	26.506	67.6858	49.3582	11.9523
792.5	25.7325	66.5542	48.6908	11.6886
797.5	25.0071	65.4212	48.0016	11.4355
802.5	24.3284	64.2878	47.2913	11.1917
807.5	23.695	63.1542	46.5606	10.9561
812.5	23.096	62.0202	45.81	10.7277
817.5	22.5214	60.886	45.0404	10.5053
822.5	21.9903	59.7516	44.2519	10.2889
827.5	21.5017	58.6169	43.4461	10.0767
832.5	21.0546	57.482	42.6233	9.8691
837.5	20.6475	56.3469	41.7919	9.6649
842.5	20.2794	55.2999	41.0271	9.4762
847.5	19.9493	54.3511	40.3351	9.3046
852.5	19.6562	53.499	39.7149	9.1497
857.5	19.3995	52.742	39.1654	9.0111
862.5	19.1789	52.0787	38.6862	8.8882
867.5	18.9938	51.508	38.2764	8.7804
872.5	18.8444	51.029	37.9343	8.6889
877.5	18.7303	50.6406	37.6596	8.6131
882.5	18.6514	50.3422	37.4527	8.5518
887.5	18.6076	50.1333	37.3124	8.5059
892.5	18.5989	50.0135	37.2388	8.4748
897.5	18.6266	49.9856	37.234	8.4593
900.0	18.6756	50.0327	37.2819	8.4588

Appendix 2B: Range graph values for case 2 (Line 1)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
0.0	31.0259	203.9981	106.8405	56.7967
2.5	30.9976	203.9228	106.8063	56.7665
7.5	38.7953	205.391	112.0986	54.0907
12.5	38.4181	205.012	111.6863	54.0774
17.5	38.0558	204.6285	111.2573	54.0595
22.5	37.7095	204.24	110.8142	54.043
27.5	37.3799	203.8466	110.3677	54.0266
32.5	37.0666	203.4484	109.9221	53.9935
37.5	36.7683	203.0458	109.5028	53.9671
42.5	36.4849	202.6391	109.1077	53.9166
47.5	36.1228	202.2288	108.7099	53.8837
52.5	35.751	201.8156	108.3054	53.8364
57.5	35.3831	201.4003	107.9089	53.7955
62.5	35.0201	200.984	107.5091	53.7581
67.5	34.6617	200.5681	107.1214	53.7221
72.5	34.3062	200.155	106.7276	53.6892
77.5	33.9515	199.7474	106.3403	53.6656
82.5	33.5964	199.3459	105.9752	53.6343
87.5	33.2395	198.9491	105.5875	53.6175
92.5	32.8801	198.5549	105.2081	53.6
97.5	32.5193	198.1622	104.8386	53.5905
102.5	32.1582	197.7701	104.4578	53.5844
107.5	31.7975	197.378	104.0932	53.5861
112.5	31.438	196.9857	103.6892	53.5776
117.5	31.0793	196.5929	103.3152	53.5889
122.5	30.7215	196.2058	102.932	53.5839
127.5	30.3647	195.8378	102.5436	53.5751
132.5	30.0089	195.4684	102.1728	53.5666
137.5	29.6542	195.0976	101.7966	53.5632
142.5	29.3005	194.7251	101.4149	53.5492
147.5	28.9479	194.3511	101.0275	53.5268
152.5	28.5962	193.9755	100.6486	53.509
157.5	28.2455	193.5983	100.2737	53.4917
162.5	27.8958	193.2196	99.909	53.4788
167.5	27.5472	192.8395	99.5536	53.4619
172.5	27.1996	192.4581	99.1839	53.4501
177.5	26.8526	192.0756	98.8208	53.441
182.5	26.5054	191.6921	98.476	53.4416
187.5	26.1404	191.3078	98.1159	53.4366
192.5	25.7572	190.9231	97.7577	53.4334
197.5	25.3789	190.5381	97.4009	53.4296

Appendix 2B: Range graph values for case 2 (Line 1)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
202.5	25.0127	190.1532	97.044	53.4257
207.5	24.6554	189.7686	96.6836	53.4152
212.5	24.2988	189.3845	96.3169	53.4094
217.5	23.9391	189.0012	95.9608	53.4012
222.5	23.5816	188.6188	95.6142	53.3852
227.5	23.2327	188.2375	95.2426	53.3785
232.5	22.8951	187.8574	94.8728	53.371
237.5	22.5713	187.4785	94.4963	53.3592
242.5	22.2627	187.1008	94.1202	53.3217
247.5	21.9685	186.7243	93.7531	53.306
252.5	21.6886	186.3489	93.3797	53.2894
257.5	21.4205	185.9753	93.0108	53.2759
262.5	21.1621	185.6082	92.6482	53.2617
267.5	20.9093	185.2415	92.2701	53.2645
272.5	20.656	184.8755	91.9191	53.2557
277.5	20.3978	184.5104	91.5805	53.2471
282.5	20.1301	184.1463	91.2418	53.2445
287.5	19.8538	183.7836	90.8904	53.2419
292.5	19.5748	183.4223	90.5457	53.2438
297.5	19.2995	183.0626	90.2047	53.2476
302.5	19.0353	182.7048	89.8639	53.2524
307.5	18.7881	182.3491	89.5262	53.255
312.5	18.5608	181.9956	89.186	53.2584
317.5	18.3545	181.6444	88.8586	53.2412
322.5	18.1684	181.2955	88.5191	53.2372
327.5	17.9972	180.9494	88.1764	53.2291
332.5	17.8326	180.6062	87.8323	53.215
337.5	17.6679	180.2658	87.4779	53.2027
342.5	17.4988	179.9281	87.1226	53.1858
347.5	17.3265	179.5926	86.7682	53.1695
352.5	17.0338	179.2589	86.4021	53.1517
357.5	16.6321	178.9268	86.0407	53.1331
362.5	16.2485	178.5955	85.6894	53.1177
367.5	15.882	178.2648	85.3229	53.1048
372.5	15.5309	177.9341	84.9545	53.0936
377.5	15.1919	177.6031	84.5941	53.0822
382.5	14.8625	177.2717	84.2309	53.0664
387.5	14.5388	176.9396	83.8788	53.0566
392.5	14.2183	176.6067	83.5348	53.0438
397.5	13.8988	176.2729	83.1774	53.0511
402.5	13.5795	175.938	82.8585	53.0459
407.5	13.2593	175.6021	82.5294	53.0406
412.5	12.9389	175.265	82.2005	53.0334
417.5	12.6184	174.9267	81.8722	53.0255
422.5	12.2984	174.5873	81.5253	53.0255

Appendix 2B: Range graph values for case 2 (Line 1)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
427.5	11.9798	174.2467	81.189	53.0174
432.5	11.6629	173.9054	80.856	53.0116
437.5	11.3473	173.5633	80.526	53.0062
442.5	11.0338	173.2208	80.1939	52.9991
447.5	10.7224	172.8781	79.8435	52.9917
452.5	10.4131	172.5356	79.499	52.9796
457.5	10.1057	172.1938	79.1638	52.9744
462.5	9.8002	171.8547	78.8392	52.9655
467.5	9.497	171.5528	78.5172	52.9583
472.5	9.196	171.2539	78.2048	52.9556
477.5	8.8971	170.9592	77.8798	52.9513
482.5	8.5999	170.6704	77.5994	52.9441
487.5	8.3046	170.3884	77.3072	52.9489
492.5	8.0107	170.1116	76.9795	52.9513
497.5	7.7167	169.8382	76.6944	52.9546
502.5	7.4222	169.5669	76.4012	52.9561
507.5	7.1253	169.2971	76.1139	52.9573
512.5	6.8252	169.0284	75.8403	52.9602
517.5	6.5205	168.7604	75.5461	52.9714
522.5	6.2101	168.4931	75.2342	52.9867
527.5	5.8964	168.2263	74.9468	53.005
532.5	5.5866	167.9599	74.6916	53.0172
537.5	5.2888	167.694	74.4068	53.0316
542.5	5.0099	167.4284	74.1193	53.0407
547.5	4.7547	167.1633	73.8283	53.0524
555.0	3.5182	165.592	72.3176	53.169
565.0	0.0	162.8474	69.8906	53.7035
575.0	0.0	168.3792	67.5861	53.9034
585.0	0.0	166.7653	65.3909	53.9841
595.0	0.0	156.2993	63.6041	54.1099
605.0	0.0	166.2778	62.1958	54.4875
615.0	0.0	163.3169	61.0373	55.0576
625.0	0.0	176.9224	59.3751	55.5121
635.0	0.0	179.245	58.4464	55.1256
645.0	0.0	164.2234	58.0155	54.6524
655.0	0.0	157.1289	57.9755	54.0317
665.0	0.0	154.1248	58.4021	52.9728
675.0	0.0	151.8694	58.7689	51.8039
685.0	1.3348	150.1616	59.2978	50.6766
695.0	2.6087	149.0997	59.9832	49.7043
705.0	4.2244	148.6112	60.4837	48.7613
715.0	6.1231	148.283	61.0664	47.8875

Appendix 2B: Range graph values for case 2 (Line 1)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
725.0	8.2367	148.0454	61.7415	47.0792
735.0	10.4339	147.8673	62.3141	46.2818
745.0	12.4822	147.7097	62.8735	45.4105
755.0	12.7999	147.5565	63.4454	44.6072
765.0	12.1937	147.4008	64.073	43.7699
775.0	11.6885	147.2937	64.7055	42.952
785.0	11.215	165.4799	65.4371	42.3207
795.0	10.5452	175.7778	66.1134	41.6728
805.0	9.8789	187.9377	66.7871	41.0603
815.0	9.3581	199.2821	67.5482	40.5365
825.0	8.9916	209.1078	68.0723	40.1879
835.0	8.7666	215.8918	67.8303	39.9493
845.0	8.6785	226.3951	67.4453	39.9151
850.0	8.7229	226.4389	67.4887	39.9145

Appendix 2B: Range graph values for case 2 (Line 2)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
0.0	34.6785	109.5736	62.2091	17.3965
2.5	34.4971	109.3307	61.9991	17.3911
7.5	34.6273	118.7764	67.0669	21.9223
12.5	34.2952	119.1132	66.6625	21.9309
17.5	33.9649	118.1055	66.2337	21.9059
22.5	33.637	116.1037	65.7891	21.8557
27.5	33.3116	113.5057	65.3387	21.8064
32.5	32.9884	110.9703	64.8929	21.759
37.5	32.667	109.3436	64.4756	21.7447
42.5	32.3469	108.0572	64.0603	21.7399
47.5	32.0275	107.0911	63.6534	21.7359
52.5	31.7085	106.5609	63.2456	21.7398
57.5	31.3898	106.1252	62.8401	21.742
62.5	31.0715	105.6288	62.4271	21.7382
67.5	30.7538	104.9336	62.0187	21.7366
72.5	30.4365	103.9663	61.6111	21.7353
77.5	30.1193	102.9635	61.1957	21.7194
82.5	29.8017	102.5967	60.7812	21.7085
87.5	29.4833	102.1617	60.3917	21.7179
92.5	29.1641	101.6446	59.9985	21.7197
97.5	28.844	101.2392	59.6128	21.7212
102.5	28.5229	100.832	59.2391	21.734
107.5	28.2006	100.4233	58.8552	21.737
112.5	27.8774	100.013	58.4536	21.7353
117.5	27.5534	99.6013	58.0688	21.7415
122.5	27.2287	99.1882	57.6822	21.7485
127.5	26.903	98.7859	57.3033	21.7551
132.5	26.5762	98.3829	56.9164	21.7595
137.5	26.2485	97.9773	56.531	21.7624
142.5	25.9202	97.8464	56.1462	21.7647
147.5	25.5705	97.6503	55.7611	21.7653
152.5	25.2056	97.2542	55.377	21.763
157.5	24.8412	96.6956	54.9917	21.7604
162.5	24.477	96.0219	54.6081	21.7598
167.5	24.1117	95.573	54.2229	21.761
172.5	23.7459	95.1845	53.8402	21.7642
177.5	23.3798	94.8029	53.4427	21.7707
182.5	23.0133	94.431	53.0559	21.7774
187.5	22.6469	94.0598	52.651	21.7686
192.5	22.2802	93.7847	52.2607	21.7674
197.5	21.9128	93.4991	51.8708	21.7614

Appendix 2B: Range graph values for case 2 (Line 2)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
202.5	21.5453	93.0577	51.4599	21.7374
207.5	21.1777	92.5742	51.0699	21.7283
212.5	20.8103	92.202	50.6948	21.729
217.5	20.4438	91.8291	50.3088	21.7164
222.5	20.0785	91.4553	49.9342	21.714
227.5	19.7146	91.0807	49.5525	21.71
232.5	19.3522	90.7051	49.1799	21.7019
237.5	18.9918	90.3286	48.8115	21.7008
242.5	18.6337	89.9511	48.4297	21.6931
247.5	18.2782	89.5726	48.0422	21.6839
252.5	17.9256	89.1931	47.6543	21.6737
257.5	17.5765	88.8128	47.2536	21.6529
262.5	17.2313	88.4317	46.8934	21.6472
267.5	16.8909	88.05	46.5204	21.6431
272.5	16.5552	87.6676	46.1493	21.6464
277.5	16.2248	87.2849	45.775	21.6478
282.5	15.9003	86.902	45.3993	21.6461
287.5	15.582	86.6993	45.0198	21.6392
292.5	15.2699	86.858	44.6377	21.6298
297.5	14.964	86.5276	44.2436	21.6062
302.5	14.6647	85.8175	43.8599	21.5923
307.5	14.3713	85.0124	43.4809	21.5767
312.5	14.0828	84.6414	43.1047	21.5568
317.5	13.7986	84.2703	42.7392	21.5566
322.5	13.5188	83.899	42.3654	21.5511
327.5	13.2441	83.5274	41.9905	21.543
332.5	12.9753	83.1554	41.6215	21.5385
337.5	12.7132	82.8096	41.2544	21.528
342.5	12.4572	82.5351	40.8986	21.5261
347.5	12.2081	82.0376	40.5421	21.5241
352.5	11.9653	81.6646	40.1767	21.5224
357.5	11.7281	81.2917	39.8128	21.5199
362.5	11.4967	80.919	39.4768	21.5348
367.5	11.2709	80.5471	39.123	21.5329
372.5	11.0498	80.1763	38.7556	21.5299
377.5	10.832	79.8072	38.3844	21.5294
382.5	10.616	79.4404	38.0137	21.5296
387.5	10.4012	79.0763	37.6432	21.525
392.5	10.1878	78.9538	37.2775	21.5503
397.5	9.977	79.4139	36.9094	21.5612
402.5	9.7703	79.4634	36.541	21.568
407.5	9.5684	79.1777	36.154	21.5642
412.5	9.3709	78.7114	35.7869	21.5637
417.5	9.1759	78.2864	35.4439	21.5723
422.5	8.9798	77.8898	35.0726	21.5662
427.5	8.7783	77.6096	34.7179	21.5641

Appendix 2B: Range graph values for case 2 (Line 2)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
725.0	1.6062	152.2363	28.4871	16.0097
735.0	1.5444	150.3984	28.9917	15.6718
745.0	1.4985	148.6397	29.6229	15.5198
755.0	1.4678	146.9348	30.3967	15.5924
765.0	1.4517	145.2383	31.1624	15.5646
775.0	1.358	143.563	31.9342	15.4951
785.0	1.2388	142.0514	32.7128	15.3623
795.0	1.0701	140.9212	33.5594	15.4298
805.0	0.8989	140.3716	34.4327	15.6674
815.0	0.9577	141.9127	35.156	16.0002
825.0	0.8948	161.0103	35.6316	17.0088
835.0	0.8315	196.7282	35.6481	18.6383
845.0	0.0	216.9816	35.5453	19.6683
850.0	0.0281	217.01	35.5739	19.6682

Appendix 2B: Range graph values for case 2 (Line 3)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
0.0	32.8849	146.2288	83.2558	36.6012
2.5	33.0985	146.3433	83.4838	36.5287
7.5	39.6063	150.3732	89.0978	35.2077
12.5	39.2631	150.0009	88.705	35.2034
17.5	38.9252	149.6266	88.3021	35.1867
22.5	38.5936	149.2501	87.8919	35.1558
27.5	38.2683	148.8712	87.4847	35.1228
32.5	37.9492	148.49	87.0793	35.1035
37.5	37.6356	148.1087	86.6832	35.0943
42.5	37.3272	147.7283	86.2873	35.098
47.5	37.024	147.3461	85.8867	35.0919
52.5	36.7257	146.9622	85.5118	35.0858
57.5	36.432	146.577	85.1518	35.0731
62.5	36.1426	146.1908	84.7695	35.0565
67.5	35.826	145.8074	84.3623	35.034
72.5	35.4891	145.4303	83.9858	35.0126
77.5	35.1488	145.0535	83.6103	34.9882
82.5	34.7928	144.6765	83.2431	34.9695
87.5	34.4101	144.2991	82.8671	34.9511
92.5	34.0199	143.9212	82.4719	34.9335
97.5	33.6303	143.5428	82.1008	34.934
102.5	33.2438	143.1641	81.7182	34.9262
107.5	32.8617	142.7849	81.3477	34.9253
112.5	32.4838	142.4053	80.9711	34.9222
117.5	32.111	142.0255	80.5973	34.9209
122.5	31.7438	141.6452	80.2247	34.9216
127.5	31.3826	141.2648	79.86	34.9281
132.5	31.027	140.884	79.4945	34.9162
137.5	30.6769	140.5031	79.1191	34.9082
142.5	30.3314	140.1221	78.7304	34.8892
147.5	29.9902	139.741	78.3508	34.8755
152.5	29.6524	139.3598	77.9701	34.8663
157.5	29.3173	138.9786	77.5939	34.8488
162.5	28.9849	138.5975	77.2147	34.8407
167.5	28.6554	138.2164	76.8359	34.8341
172.5	28.3293	137.8355	76.4609	34.8206
177.5	28.0075	137.4549	76.0741	34.8005
182.5	27.6905	137.0746	75.6927	34.7944
187.5	27.3629	136.6946	75.3114	34.7886
192.5	26.9936	136.3151	74.9354	34.7799
197.5	26.6277	135.9361	74.5581	34.782

Appendix 2B: Range graph values for case 2 (Line 3)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
202.5	26.2658	135.5578	74.1927	34.7765
207.5	25.9084	135.1834	73.8243	34.7651
212.5	25.5559	134.8141	73.4531	34.7555
217.5	25.208	134.4454	73.0779	34.7489
222.5	24.8648	134.0769	72.7185	34.7433
227.5	24.526	133.7088	72.3519	34.7377
232.5	24.191	133.3408	71.9791	34.7264
237.5	23.8593	132.973	71.6034	34.7166
242.5	23.5305	132.6054	71.2064	34.7034
247.5	23.2047	132.2379	70.8312	34.6938
252.5	22.8821	131.8706	70.4568	34.685
257.5	22.5635	131.5035	70.0821	34.6791
262.5	22.25	131.1366	69.7436	34.6847
267.5	21.9426	130.7698	69.3784	34.6786
272.5	21.6423	130.4033	69.0127	34.669
277.5	21.3493	130.037	68.6504	34.6611
282.5	21.0632	129.6711	68.2807	34.6379
287.5	20.7833	129.3053	67.8998	34.6255
292.5	20.5078	128.94	67.5188	34.6242
297.5	20.2341	128.575	67.1411	34.6035
302.5	19.9577	128.2104	66.773	34.5951
307.5	19.6422	127.8464	66.4262	34.6001
312.5	19.3125	127.4829	66.0636	34.5903
317.5	18.9857	127.12	65.6741	34.5784
322.5	18.6619	126.7579	65.3036	34.5654
327.5	18.341	126.3965	64.9454	34.5771
332.5	18.0231	126.0361	64.5997	34.5752
337.5	17.7082	125.6772	64.2649	34.5757
342.5	17.3968	125.3201	63.936	34.578
347.5	17.0896	124.9648	63.6014	34.5783
352.5	16.7876	124.6115	63.2758	34.5844
357.5	16.4913	124.2596	62.9331	34.5917
362.5	16.2017	123.9087	62.5879	34.589
367.5	15.9192	123.5587	62.2373	34.5853
372.5	15.6439	123.2096	61.8822	34.5796
377.5	15.3761	122.8613	61.5258	34.5702
382.5	15.1152	122.5138	61.1695	34.5586
387.5	14.8607	122.1669	60.8329	34.5343
392.5	14.6116	121.8206	60.4748	34.5202
397.5	14.3665	121.475	60.1206	34.5078
402.5	14.124	121.1299	59.7563	34.4964
407.5	13.8817	120.7853	59.408	34.491
412.5	13.6378	120.4414	59.0603	34.4747
417.5	13.391	120.0981	58.7111	34.4697
422.5	13.1413	119.7555	58.3632	34.4639
427.5	12.89	119.4136	58.0181	34.4577

Appendix 2B: Range graph values for case 2 (Line 3)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
432.5	12.6392	119.0724	57.68	34.4543
437.5	12.3901	118.732	57.328	34.4465
442.5	12.1439	118.3924	56.9885	34.4403
447.5	11.9023	118.0536	56.6474	34.4331
452.5	11.666	117.7158	56.3161	34.4181
457.5	11.4363	117.3788	55.9893	34.4028
462.5	11.214	117.0429	55.653	34.3896
467.5	10.9995	116.7082	55.3262	34.3824
472.5	10.7927	116.3747	54.9976	34.3743
477.5	10.5928	116.0426	54.6789	34.3709
482.5	10.3975	115.7121	54.3842	34.3756
487.5	10.2029	115.3842	54.0551	34.3763
492.5	10.0006	115.0615	53.7316	34.3748
497.5	9.7496	114.741	53.4109	34.376
502.5	9.4712	114.4224	53.0815	34.3724
507.5	9.1966	114.1057	52.7408	34.3835
512.5	8.9266	113.7909	52.4156	34.3895
517.5	8.6621	113.4781	52.087	34.4057
522.5	8.4039	113.1674	51.7714	34.4155
527.5	8.1529	112.8588	51.4505	34.4321
532.5	7.9106	112.5527	51.1316	34.4503
537.5	7.6776	112.2491	50.8182	34.4655
542.5	7.454	111.9481	50.5336	34.4778
547.5	7.2399	111.6502	50.2283	34.4875
555.0	3.771	112.6775	48.6711	34.7922
565.0	0.0	160.4834	46.1499	35.6986
575.0	0.0	168.416	43.7384	36.0142
585.0	0.0	210.1687	41.4974	36.4851
595.0	0.0	170.6827	40.2355	37.7528
605.0	0.0	186.7041	38.4387	38.4154
615.0	0.0	169.9507	36.6225	37.3447
625.0	0.0	182.3847	36.1908	37.0927
635.0	0.0	161.3274	36.2337	36.1487
645.0	0.0	154.3991	36.8253	34.9535
655.0	0.0	150.2815	37.4926	33.8475
665.0	0.0	147.487	38.2229	32.8405
675.0	0.0	145.424	38.9746	31.8979
685.0	1.6955	143.7304	39.7397	30.9967
695.0	3.378	142.4272	40.4956	30.145
705.0	3.8357	141.3638	41.2477	29.3243
715.0	3.55	140.2958	41.9995	28.4837
725.0	2.6191	139.3428	42.7191	27.6027

Appendix 2B: Range graph values for case 2 (Line 3)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
735.0	0.0166	138.6044	43.3687	26.7124
745.0	1.1695	138.0816	43.9334	25.8362
755.0	2.9189	137.5956	44.3949	24.9638
765.0	2.8651	136.7797	44.6106	24.0068
775.0	2.8468	135.9193	45.0039	23.2016
785.0	2.5581	134.997	45.5217	22.6539
795.0	2.04	134.3094	46.1756	22.3181
805.0	1.6632	148.7815	47.0284	22.2273
815.0	1.4157	166.0219	48.0635	22.7427
825.0	1.2461	183.2344	48.633	23.342
835.0	1.0956	198.6172	48.4717	23.952
845.0	0.0	212.0885	48.2323	24.5065
850.0	0.0343	212.1235	48.2672	24.5062

Appendix 2B: Range graph values for case 2 (Line 4)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
0.0	30.6776	86.6872	53.1482	11.5296
2.5	30.5425	86.8991	53.2107	11.6705
7.5	31.4359	96.4602	57.8349	14.5497
12.5	31.1014	97.0279	57.4445	14.5963
17.5	30.7832	96.382	57.0438	14.6195
22.5	30.4786	94.8262	56.6109	14.6079
27.5	30.1834	92.9728	56.1827	14.5894
32.5	29.8928	92.9673	55.7556	14.5706
37.5	29.6001	92.9106	55.3551	14.5734
42.5	29.3012	92.8001	54.9471	14.5844
47.5	28.9945	92.6365	54.5521	14.6008
52.5	28.6812	92.4215	54.1404	14.6013
57.5	28.3642	92.1514	53.7271	14.5889
62.5	28.0461	91.834	53.3202	14.5885
67.5	27.7276	91.4654	52.9167	14.589
72.5	27.4089	91.055	52.5158	14.5882
77.5	27.0909	90.6039	52.1122	14.5872
82.5	26.7737	90.1166	51.7122	14.5796
87.5	26.4573	89.5985	51.3184	14.5764
92.5	26.1427	89.054	50.9177	14.557
97.5	25.8297	88.4871	50.5179	14.5288
102.5	25.5179	87.9013	50.127	14.5044
107.5	25.2073	87.3003	49.7326	14.4842
112.5	24.8975	86.6877	49.3411	14.4659
117.5	24.5887	86.067	48.9506	14.449
122.5	24.2819	85.441	48.5563	14.4354
127.5	23.9772	84.815	48.1623	14.4317
132.5	23.6743	84.3575	47.7748	14.4355
137.5	23.3728	84.2168	47.3893	14.4382
142.5	23.0723	84.0611	47.0009	14.4333
147.5	22.7727	83.914	46.6094	14.4153
152.5	22.475	83.7301	46.2138	14.3932
157.5	22.1797	83.513	45.799	14.3567
162.5	21.8866	83.3112	45.4033	14.3357
167.5	21.5954	83.0938	45.0123	14.3246
172.5	21.2826	82.8546	44.6328	14.3409
177.5	20.9717	82.6394	44.2349	14.3362
182.5	20.6631	82.4327	43.8253	14.3173
187.5	20.358	82.225	43.4554	14.3349
192.5	20.0577	82.075	43.0648	14.3384
197.5	19.7634	81.9351	42.673	14.3361

Appendix 2B: Range graph values for case 2 (Line 4)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
202.5	19.4758	81.7856	42.2765	14.3258
207.5	19.1943	81.674	41.9106	14.3332
212.5	18.9175	81.5405	41.4879	14.3063
217.5	18.6419	81.3737	41.1157	14.3097
222.5	18.3614	81.2099	40.7278	14.2998
227.5	18.0695	81.0191	40.3422	14.2961
232.5	17.7697	80.7756	39.9792	14.3102
237.5	17.4675	80.4852	39.5905	14.3121
242.5	17.1647	80.174	39.2042	14.3165
247.5	16.862	79.7823	38.8293	14.3277
252.5	16.5597	79.2968	38.4395	14.3277
257.5	16.2583	78.7246	38.0475	14.3258
262.5	15.9579	78.0943	37.666	14.3183
267.5	15.6588	77.3755	37.2956	14.3233
272.5	15.3608	76.5732	36.9132	14.3162
277.5	15.0639	75.7047	36.5279	14.3157
282.5	14.7679	74.765	36.1423	14.3199
287.5	14.473	73.7127	35.7554	14.3259
292.5	14.1795	72.5507	35.3688	14.3256
297.5	13.8875	71.2992	34.9829	14.324
302.5	13.5972	69.9591	34.5983	14.3219
307.5	13.3085	68.4601	34.2101	14.3124
312.5	13.0213	66.9037	33.8342	14.3136
317.5	12.7354	66.2957	33.462	14.3125
322.5	12.4508	65.7108	33.0766	14.2893
327.5	12.1677	65.3279	32.7109	14.2848
332.5	11.8865	64.9461	32.3572	14.3071
337.5	11.6074	64.5649	31.9864	14.3144
342.5	11.3303	64.1843	31.6106	14.3209
347.5	11.0551	63.8043	31.231	14.3203
352.5	10.7818	63.4256	30.8487	14.3068
357.5	10.5103	63.048	30.4595	14.3029
362.5	10.2412	62.6712	30.0882	14.3046
367.5	9.9746	63.5308	29.7191	14.3085
372.5	9.7105	65.3654	29.3491	14.3149
377.5	9.4492	66.2163	28.99	14.3317
382.5	9.1903	66.1635	28.6289	14.3463
387.5	8.9335	65.5297	28.2481	14.3381
392.5	8.6791	64.6587	27.8787	14.3361
397.5	8.4271	63.8695	27.5069	14.3256
402.5	8.1783	63.2857	27.1381	14.3293
407.5	7.9331	62.8671	26.7936	14.3379
412.5	7.6912	62.652	26.4317	14.3348
417.5	7.4529	62.4701	26.0742	14.3351
422.5	7.2179	62.3521	25.7248	14.3385
427.5	6.9859	62.2699	25.3805	14.3425

Appendix 2B: Range graph values for case 2 (Line 4)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
432.5	6.7574	62.1398	25.0434	14.3495
437.5	6.5326	62.004	24.7089	14.3617
442.5	6.3118	61.8965	24.342	14.3558
447.5	6.0951	61.727	23.9997	14.3706
452.5	5.8822	61.5201	23.6563	14.38
457.5	5.6732	61.38	23.311	14.3899
462.5	5.4678	61.1908	22.9621	14.4004
467.5	5.2665	60.9671	22.6073	14.4098
472.5	5.0697	60.8593	22.2577	14.4176
477.5	4.8776	60.7145	21.9142	14.4359
482.5	4.6905	60.5253	21.5343	14.4209
487.5	4.5084	60.4363	21.1891	14.4281
492.5	4.3308	60.2728	20.8473	14.4367
497.5	4.1573	60.011	20.4942	14.4291
502.5	3.9873	59.7507	20.1633	14.4435
507.5	3.8204	59.4288	19.7886	14.4281
512.5	3.2638	58.9924	19.4415	14.4522
517.5	1.9075	58.5188	19.0894	14.4818
522.5	0.755	58.0908	18.7352	14.5152
527.5	0.0434	57.6053	18.3872	14.5498
532.5	0.0	57.1387	18.046	14.58
537.5	0.0	56.8064	17.7144	14.6089
542.5	0.0	56.4613	17.3875	14.6364
547.5	0.0	56.1799	17.0672	14.6606
555.0	0.0	91.5579	16.0178	16.9296
565.0	0.0	208.6985	15.9424	28.3812
575.0	0.0	202.4549	12.0795	23.0374
585.0	0.0	190.321	11.0769	20.2672
595.0	0.0	153.872	11.379	18.1824
605.0	0.0	136.5787	12.3899	16.1886
615.0	0.0	125.4092	13.6177	14.8325
625.0	0.0	117.8351	14.5868	13.7947
635.0	0.7567	111.644	15.2631	12.7293
645.0	0.6923	106.5963	15.9142	12.0114
655.0	0.6353	102.3244	16.4625	11.4226
665.0	0.5832	99.9769	16.8906	10.9281
675.0	0.5373	97.7725	17.2324	10.5192
685.0	0.4958	95.5065	17.4822	10.1716
695.0	0.4587	93.2768	17.6447	9.8774
705.0	0.4249	91.1261	17.7219	9.6284
715.0	0.3945	88.9971	17.7163	9.3946
725.0	0.3676	86.8105	17.6363	9.1509

Appendix 2B: Range graph values for case 2 (Line 4)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
735.0	0.3291	84.5735	17.5078	8.9259
745.0	0.2917	82.3809	17.3206	8.6849
755.0	0.2566	80.2227	17.0981	8.4452
765.0	0.22	78.0507	16.8251	8.2183
775.0	0.1837	75.9312	16.5351	7.9902
785.0	0.1501	74.4119	16.2351	7.8725
795.0	0.1186	74.618	15.8922	7.9516
805.0	0.0877	77.1545	15.3759	7.6605
815.0	0.0584	77.8975	14.8748	7.2302
825.0	0.0246	74.6581	14.5229	7.1613
835.0	0.0	89.2721	14.3386	7.6248
845.0	0.0	106.6217	14.2682	8.2894
850.0	-0.0131	106.6087	14.2552	8.2894

Appendix 2B: Range graph values for case 2 (Line 5)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
0.0	35.6767	117.1435	62.4783	19.6205
2.5	35.6956	117.2522	62.6212	19.6881
7.5	38.8559	124.2674	67.9785	21.1696
12.5	38.5309	124.0857	67.5702	21.18
17.5	38.2104	122.5127	67.1436	21.1524
22.5	37.8942	119.8878	66.6949	21.0821
27.5	37.5811	116.6088	66.2483	21.0008
32.5	37.2697	113.1643	65.8186	20.93
37.5	36.959	111.4587	65.4117	20.8875
42.5	36.6454	110.3507	65.0164	20.8627
47.5	36.2723	109.3094	64.6128	20.8332
52.5	35.9009	108.5903	64.2203	20.8126
57.5	35.5321	107.8962	63.8159	20.7685
62.5	35.1666	107.2995	63.4387	20.7421
67.5	34.8051	106.536	63.055	20.7212
72.5	34.4481	105.8217	62.6646	20.7103
77.5	34.096	105.4177	62.2581	20.693
82.5	33.7492	104.8245	61.8762	20.7149
87.5	33.4077	103.9679	61.4864	20.725
92.5	33.0714	102.8005	61.0846	20.7168
97.5	32.7402	102.2757	60.7008	20.7251
102.5	32.4139	102.2102	60.2981	20.7086
107.5	32.0922	102.0994	59.9139	20.7134
112.5	31.7747	102.2937	59.5218	20.7081
117.5	31.4611	102.1439	59.145	20.7094
122.5	31.1503	101.6173	58.7733	20.7057
127.5	30.8414	101.2702	58.4076	20.6999
132.5	30.5326	101.1184	58.0281	20.6978
137.5	30.222	100.7621	57.6452	20.7193
142.5	29.9095	100.677	57.2565	20.7423
147.5	29.597	100.4873	56.8681	20.7585
152.5	29.286	100.0479	56.473	20.7656
157.5	28.9775	99.5961	56.079	20.7659
162.5	28.6724	99.3696	55.6975	20.7665
167.5	28.3707	98.8743	55.3022	20.7595
172.5	28.0726	98.3401	54.9367	20.7791
177.5	27.7779	97.8371	54.5577	20.7863
182.5	27.472	97.2524	54.1619	20.776
187.5	27.1515	96.6107	53.7872	20.7797
192.5	26.835	95.948	53.4286	20.7996
197.5	26.5224	95.4861	53.0518	20.8009

Appendix 2B: Range graph values for case 2 (Line 5)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
202.5	26.2133	95.336	52.6687	20.7988
207.5	25.9075	94.918	52.2835	20.794
212.5	25.6044	94.1623	51.9121	20.8146
217.5	25.3031	94.1452	51.5424	20.8185
222.5	25.0025	93.7949	51.1626	20.811
227.5	24.6997	93.5593	50.7654	20.7961
232.5	24.3941	93.2976	50.3869	20.7849
237.5	24.0882	92.9314	50.0176	20.7721
242.5	23.7837	92.7577	49.6284	20.7591
247.5	23.4815	92.2163	49.2584	20.7409
252.5	23.1821	92.2757	48.8972	20.7428
257.5	22.8855	91.9176	48.5277	20.7079
262.5	22.5917	91.208	48.158	20.6792
267.5	22.3003	91.226	47.7825	20.6634
272.5	22.0106	90.7269	47.3933	20.6489
277.5	21.722	89.898	47.0343	20.6644
282.5	21.4339	89.4798	46.6587	20.6583
287.5	21.1462	89.1587	46.2918	20.6583
292.5	20.8592	88.5188	45.9262	20.664
297.5	20.5733	87.7543	45.5738	20.677
302.5	20.2882	87.6406	45.1978	20.6681
307.5	20.0037	87.0762	44.8155	20.6467
312.5	19.7195	86.1554	44.4411	20.6434
317.5	19.4356	85.195	44.0385	20.6094
322.5	19.1524	84.6469	43.6666	20.5934
327.5	18.8703	84.0129	43.3056	20.5817
332.5	18.5893	83.6708	42.9534	20.5867
337.5	18.3092	84.6566	42.5905	20.5823
342.5	18.0298	85.2373	42.2355	20.5837
347.5	17.751	85.4608	41.8832	20.5801
352.5	17.4732	85.8091	41.5237	20.5768
357.5	17.1967	85.6968	41.1897	20.5843
362.5	16.9217	85.4025	40.8477	20.5938
367.5	16.6482	85.1959	40.5112	20.6218
372.5	16.3762	84.6999	40.1457	20.6338
377.5	16.1055	84.1459	39.7942	20.6621
382.5	15.836	83.6985	39.4413	20.6806
387.5	15.5147	83.1672	39.101	20.7115
392.5	15.1708	82.9082	38.7428	20.7234
397.5	14.8291	82.7423	38.3775	20.7276
402.5	14.4897	82.529	38.0101	20.7216
407.5	14.1522	82.3808	37.6356	20.704
412.5	13.8168	82.1699	37.2845	20.6915
417.5	13.4834	81.8751	36.9045	20.6727
422.5	13.1522	81.5285	36.533	20.6665
427.5	12.8235	81.2179	36.1328	20.6431

Appendix 2B: Range graph values for case 2 (Line 5)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
432.5	12.4974	80.8911	35.7704	20.6477
437.5	12.1742	80.5635	35.4117	20.6546
442.5	11.8535	80.3285	35.0373	20.644
447.5	11.5355	80.0552	34.6898	20.6486
452.5	11.22	79.7324	34.3369	20.6527
457.5	10.9071	79.5312	34.0081	20.6756
462.5	10.597	79.7236	33.654	20.6671
467.5	10.2899	80.0604	33.3099	20.6557
472.5	9.986	80.5493	32.9811	20.6492
477.5	9.6853	80.9184	32.6754	20.669
482.5	9.3876	81.0534	32.383	20.7026
487.5	9.093	80.8999	32.0536	20.7201
492.5	8.8014	80.6156	31.7472	20.7465
497.5	8.5125	80.4741	31.4394	20.7704
502.5	8.2265	80.0731	31.1366	20.7888
507.5	7.9435	79.5266	30.8155	20.8091
512.5	7.6635	78.933	30.4786	20.8417
517.5	7.3867	78.3401	30.1156	20.8638
522.5	7.113	77.7423	29.7473	20.8852
527.5	6.4849	77.3263	29.3895	20.9159
532.5	5.2508	77.4227	29.0431	20.9474
537.5	4.1479	77.614	28.7001	20.9893
542.5	3.1435	77.6335	28.3696	21.0199
547.5	2.3843	77.2626	28.048	21.0443
555.0	0.0	101.6674	26.7791	22.5163
565.0	0.0	142.4151	24.8466	25.7646
575.0	0.0	172.6407	23.4999	29.686
585.0	0.0	209.6552	20.8767	30.423
595.0	0.0	184.908	18.3736	25.5047
605.0	0.0	167.3907	17.8785	24.5303
615.0	0.0	162.9949	18.3119	23.3222
625.0	0.0	161.036	19.3179	22.126
635.0	0.0	159.5341	20.3795	21.1292
645.0	0.0	158.2605	21.5443	20.2512
655.0	0.0	157.3817	22.6013	19.4097
665.0	0.3212	156.5999	23.4248	18.5961
675.0	1.1603	155.2823	24.018	17.8905
685.0	1.3235	153.8118	24.6086	17.2134
695.0	1.2387	152.2831	25.2763	16.6646
705.0	1.1672	150.8644	25.9547	16.1443
715.0	1.1063	149.451	26.7379	15.7849
725.0	1.0558	148.028	27.5114	15.3896

Appendix 2B: Range graph values for case 2 (Line 5)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
735.0	1.0148	146.6576	28.339	15.1013
745.0	0.937	145.3842	29.2552	14.9906
755.0	0.8554	144.1445	30.2692	15.1132
765.0	0.7782	142.8678	31.1984	14.9907
775.0	0.7052	141.5869	32.2248	15.0915
785.0	0.6384	140.4484	33.2602	15.1743
795.0	0.5796	139.7111	34.4093	15.4434
805.0	0.5289	139.6008	35.6024	15.7831
815.0	0.4848	141.6963	36.6879	16.2477
825.0	0.4473	169.0907	37.5031	17.9076
835.0	0.4185	199.0988	37.5821	19.4033
845.0	0.3863	215.3813	37.3957	20.3089
850.0	0.4002	215.3943	37.4089	20.3087

Appendix 2B: Range graph values for case 2 (Line 6)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
0.0	36.2952	177.9281	97.6596	45.2197
2.5	36.1036	177.731	97.4505	45.2231
7.5	37.4519	182.7406	100.1763	46.4346
12.5	37.1127	182.3562	99.7215	46.4435
17.5	36.779	181.9713	99.2841	46.4472
22.5	36.4466	181.5855	98.8372	46.4565
27.5	36.116	181.1987	98.4168	46.4726
32.5	35.7864	180.8108	97.9842	46.4793
37.5	35.4576	180.4218	97.566	46.4805
42.5	35.1293	180.0318	97.158	46.4736
47.5	34.8021	179.6407	96.7747	46.4614
52.5	34.4768	179.2488	96.385	46.4456
57.5	34.1548	178.8561	95.9872	46.4314
62.5	33.837	178.4628	95.6097	46.4101
67.5	33.5247	178.0689	95.2168	46.396
72.5	33.2191	177.6746	94.8205	46.3871
77.5	32.9222	177.28	94.4218	46.3886
82.5	32.6352	176.8851	94.0246	46.384
87.5	32.3592	176.4902	93.6344	46.3828
92.5	32.0948	176.0953	93.2325	46.3768
97.5	31.8428	175.7005	92.8482	46.3715
102.5	31.6028	175.3059	92.456	46.3647
107.5	31.3749	174.9115	92.0619	46.3604
112.5	31.1589	174.5173	91.6654	46.3537
117.5	30.9541	174.1233	91.2762	46.345
122.5	30.7582	173.7296	90.8842	46.3343
127.5	30.5686	173.3363	90.5051	46.3259
132.5	30.3805	172.9435	90.116	46.3183
137.5	30.044	172.551	89.7196	46.3103
142.5	29.6279	172.159	89.3417	46.2906
147.5	29.2265	171.7674	88.9584	46.282
152.5	28.8399	171.3763	88.5572	46.2731
157.5	28.4684	170.9857	88.1807	46.2551
162.5	28.1106	170.5956	87.8024	46.2447
167.5	27.7665	170.206	87.4153	46.2358
172.5	27.4343	169.8169	87.0329	46.2255
177.5	27.1111	169.4285	86.663	46.2063
182.5	26.7927	169.0406	86.2813	46.1973
187.5	26.4736	168.6533	85.9056	46.19
192.5	26.1519	168.2666	85.5237	46.1837
197.5	25.8307	167.8806	85.1435	46.1744

Appendix 2B: Range graph values for case 2 (Line 6)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
202.5	25.5156	167.4953	84.7717	46.1571
207.5	25.2094	167.1106	84.3953	46.1479
212.5	24.9139	166.7266	84.0186	46.1417
217.5	24.6286	166.3434	83.6407	46.134
222.5	24.3517	165.961	83.2694	46.1257
227.5	24.0764	165.5795	82.9014	46.1077
232.5	23.7483	165.1988	82.5114	46.0987
237.5	23.4167	164.819	82.1288	46.0901
242.5	23.0978	164.44	81.7393	46.083
247.5	22.795	164.0619	81.3566	46.0741
252.5	22.5087	163.6848	80.98	46.0647
257.5	22.2372	163.3085	80.6043	46.0535
262.5	21.977	162.9332	80.2324	46.0427
267.5	21.7239	162.5588	79.8633	46.0316
272.5	21.42	162.1854	79.4959	46.0221
277.5	21.0853	161.8129	79.1181	46.0229
282.5	20.7464	161.4413	78.7503	46.0139
287.5	20.4042	161.0706	78.3853	46.0046
292.5	20.0604	160.7009	78.0195	45.9984
297.5	19.7169	160.3321	77.6498	45.996
302.5	19.3756	159.9644	77.2907	45.9885
307.5	19.038	159.5977	76.9414	45.9826
312.5	18.7049	159.232	76.5806	45.9808
317.5	18.3775	158.8674	76.2338	45.9727
322.5	18.0564	158.5039	75.8911	45.9642
327.5	17.7418	158.1415	75.5345	45.9596
332.5	17.4339	157.7802	75.1831	45.9558
337.5	17.1324	157.4201	74.8174	45.9612
342.5	16.8365	157.0612	74.4543	45.9615
347.5	16.5441	156.7037	74.0934	45.9579
352.5	16.2422	156.3476	73.7311	45.9549
357.5	15.9397	155.9928	73.3719	45.9524
362.5	15.642	155.6394	73.0101	45.9491
367.5	15.3501	155.2875	72.6629	45.9377
372.5	15.0648	154.937	72.2986	45.9439
377.5	14.7862	154.5881	71.9521	45.9365
382.5	14.5141	154.2409	71.6304	45.9136
387.5	14.2481	153.8954	71.2915	45.9026
392.5	13.9871	153.5514	70.9525	45.8937
397.5	13.7183	153.2091	70.6104	45.8873
402.5	13.4252	152.8684	70.2707	45.8846
407.5	13.1399	152.5295	69.9327	45.881
412.5	12.8633	152.1924	69.5687	45.8882
417.5	12.5948	151.8571	69.231	45.8849
422.5	12.3334	151.5237	68.8935	45.882

Appendix 2B: Range graph values for case 2 (Line 6)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
427.5	12.0788	151.192	68.5613	45.8791
432.5	11.8295	150.8623	68.2331	45.8698
437.5	11.5843	150.5345	67.907	45.8622
442.5	11.3419	150.2087	67.587	45.8504
447.5	11.1005	149.8852	67.2671	45.8433
452.5	10.8598	149.564	66.9426	45.8379
457.5	10.6188	149.2451	66.6386	45.8286
462.5	10.3771	148.9285	66.3315	45.8196
467.5	10.1358	148.6144	66.0225	45.8165
472.5	9.8953	148.3031	65.7216	45.8157
477.5	9.6582	147.9945	65.4169	45.8145
482.5	9.4262	147.6889	65.1114	45.8125
487.5	9.201	147.3861	64.7931	45.8112
492.5	8.9836	147.0863	64.4924	45.8096
497.5	8.7743	146.7898	64.169	45.8166
502.5	8.5737	146.4967	63.8636	45.8249
507.5	8.3815	146.207	63.5566	45.8305
512.5	8.1972	145.9209	63.2799	45.8372
517.5	8.0195	145.6382	62.9908	45.8365
522.5	7.8463	145.3593	62.7058	45.8435
527.5	7.6756	145.0844	62.4297	45.8474
532.5	7.5029	144.8136	62.1445	45.8597
537.5	7.3255	144.5471	61.8836	45.8611
542.5	7.1297	144.285	61.6235	45.8638
547.5	6.9132	144.0274	61.3581	45.8737
555.0	4.646	142.5748	60.0277	45.9261
565.0	0.0	140.1263	57.858	46.1502
575.0	0.0	138.0496	55.9077	46.2455
585.0	0.0	136.337	54.1239	46.5148
595.0	0.0	134.9675	53.0004	46.8851
605.0	0.0	133.9274	51.0086	47.1111
615.0	0.0	133.1819	50.2528	46.8897
625.0	0.0	132.6482	49.8091	46.6058
635.0	0.9776	132.3462	49.8253	45.8248
645.0	2.9024	132.2715	50.115	44.7326
655.0	4.7051	132.0694	50.5316	43.5173
665.0	6.7167	130.8874	51.1617	42.3962
675.0	8.8549	130.6564	51.8823	41.4655
685.0	10.7463	130.5378	52.6634	40.6075
695.0	9.9439	130.4699	53.4522	39.7712
705.0	9.2434	130.4192	54.2802	38.9158
715.0	8.6348	130.2099	55.054	37.9615
725.0	8.1097	128.6471	55.7483	36.8344

Appendix 2B: Range graph values for case 2 (Line 6)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
735.0	7.6618	126.5397	56.3546	35.529
745.0	7.2846	124.2935	56.8895	34.1774
755.0	6.9727	122.0377	57.3696	32.8415
765.0	6.7215	119.7792	57.8078	31.5558
775.0	6.527	117.5172	58.0954	30.3861
785.0	6.3825	115.2517	58.043	29.3707
795.0	6.2596	112.9835	57.7192	28.4962
805.0	5.9894	110.9165	57.3343	27.8519
815.0	5.6559	109.0199	56.7961	27.3651
825.0	5.4067	118.2609	56.0526	26.9367
835.0	5.2616	128.1964	55.3739	26.6517
845.0	5.229	136.8513	55.0882	26.5998
850.0	5.2887	136.9105	55.147	26.5994

Appendix 2B: Range graph values for case 2 (Line 7)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
0.0	32.1216	127.4871	75.8329	27.3411
2.5	31.9358	127.2782	75.6227	27.3381
7.5	31.9121	139.7718	79.8152	31.3811
12.5	31.5903	139.3853	79.3866	31.3777
17.5	31.2959	138.998	78.9443	31.3655
22.5	31.0278	138.6097	78.4868	31.3481
27.5	30.7832	138.2201	78.0492	31.335
32.5	30.5587	137.8292	77.6302	31.3262
37.5	30.3512	137.437	77.2268	31.3265
42.5	30.1562	137.0433	76.8055	31.311
47.5	29.9659	136.6484	76.4093	31.3007
52.5	29.748	136.2522	76.0179	31.2853
57.5	29.4541	135.8548	75.6253	31.2723
62.5	29.118	135.4563	75.2255	31.2666
67.5	28.7854	135.0568	74.8228	31.2582
72.5	28.4299	134.6565	74.4153	31.2543
77.5	28.0648	134.2555	74.0104	31.2483
82.5	27.6966	133.8542	73.6043	31.238
87.5	27.326	133.4526	73.2056	31.2299
92.5	26.954	133.0507	72.8112	31.2211
97.5	26.5805	132.6483	72.4182	31.2155
102.5	26.2063	132.2455	72.0252	31.21
107.5	25.83	131.8423	71.6366	31.2036
112.5	25.4527	131.4387	71.2467	31.1991
117.5	25.0741	131.0348	70.8539	31.1948
122.5	24.6949	130.6306	70.4316	31.2
127.5	24.316	130.2263	70.0375	31.198
132.5	23.9373	129.8218	69.6453	31.1977
137.5	23.5594	129.4172	69.2571	31.1955
142.5	23.1829	129.0128	68.8724	31.1924
147.5	22.8086	128.6087	68.4886	31.1891
152.5	22.4369	128.2049	68.1057	31.1807
157.5	22.0684	127.8014	67.7175	31.1738
162.5	21.7031	127.3983	67.3261	31.1651
167.5	21.341	126.9956	66.9292	31.1595
172.5	20.9816	126.5932	66.5313	31.1443
177.5	20.6247	126.1909	66.1333	31.1382
182.5	20.2707	125.7887	65.7382	31.133
187.5	19.9201	125.3867	65.3477	31.1283
192.5	19.5731	124.9849	64.9796	31.118
197.5	19.2303	124.5832	64.5877	31.1147

Appendix 2B: Range graph values for case 2 (Line 7)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
202.5	18.8921	124.1817	64.198	31.1089
207.5	18.5589	123.7804	63.8101	31.0965
212.5	18.2311	123.3794	63.4135	31.084
217.5	17.909	122.9785	63.0193	31.0811
222.5	17.593	122.5779	62.6285	31.0756
227.5	17.283	122.1775	62.2459	31.0606
232.5	16.9785	121.7774	61.8569	31.0514
237.5	16.6789	121.3775	61.4616	31.0492
242.5	16.3831	120.9781	61.0706	31.0419
247.5	16.0902	120.5791	60.6851	31.0315
252.5	15.7991	120.1808	60.3018	31.0191
257.5	15.5094	119.7835	59.9241	31.0003
262.5	15.2202	119.3877	59.5415	30.9897
267.5	14.9324	118.9946	59.1577	30.9804
272.5	14.6471	118.6025	58.7759	30.9711
277.5	14.3653	118.2111	58.3977	30.9656
282.5	14.0877	117.8205	58.0297	30.9535
287.5	13.8151	117.4307	57.6576	30.9469
292.5	13.548	117.0417	57.2965	30.9354
297.5	13.2868	116.6534	56.9256	30.9322
302.5	13.031	116.2678	56.5596	30.9283
307.5	12.7809	115.8848	56.1904	30.915
312.5	12.5354	115.5029	55.8131	30.914
317.5	12.2934	115.1219	55.4332	30.9176
322.5	12.0536	114.7418	55.0613	30.9137
327.5	11.8152	114.3626	54.6658	30.9217
332.5	11.5791	113.9843	54.3055	30.9194
337.5	11.3468	113.607	53.9423	30.9167
342.5	11.1202	113.2309	53.5836	30.9129
347.5	10.9007	112.856	53.2205	30.9123
352.5	10.69	112.4824	52.8659	30.9079
357.5	10.4891	112.1103	52.5092	30.9067
362.5	10.2984	111.7395	52.1567	30.8987
367.5	10.118	111.3704	51.7995	30.8836
372.5	9.9476	111.0039	51.4539	30.8671
377.5	9.7857	110.6397	51.105	30.8567
382.5	9.63	110.2773	50.7517	30.8521
387.5	9.4767	109.917	50.3964	30.8492
392.5	9.3197	109.5588	50.0349	30.8496
397.5	9.1372	109.2022	49.6739	30.8468
402.5	8.9165	108.8473	49.313	30.8432
407.5	8.7021	108.4939	48.9808	30.8293
412.5	8.496	108.1421	48.631	30.8226
417.5	8.2984	107.7921	48.291	30.8172
422.5	8.1115	107.4439	47.9598	30.8091
427.5	7.9346	107.0976	47.6298	30.8054

Appendix 2B: Range graph values for case 2 (Line 7)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
432.5	7.7681	106.7532	47.3003	30.8034
437.5	7.6116	106.4107	46.9615	30.8006
442.5	7.448	106.07	46.6294	30.7979
447.5	7.2287	105.7314	46.2959	30.7962
452.5	7.0128	105.3949	45.9623	30.7961
457.5	6.7998	105.0611	45.6347	30.7947
462.5	6.5896	104.7299	45.3177	30.7907
467.5	6.3832	104.4014	45.0055	30.7859
472.5	6.1817	104.0757	44.6989	30.7822
477.5	5.9863	103.7532	44.3874	30.7782
482.5	5.7315	103.435	44.0739	30.7748
487.5	5.4675	103.1205	43.7506	30.774
492.5	5.2304	102.8095	43.4322	30.7779
497.5	5.0202	102.5026	43.112	30.7875
502.5	4.8357	102.1994	42.7883	30.7934
507.5	4.675	101.9	42.4806	30.8086
512.5	4.4056	101.6045	42.1752	30.8114
517.5	3.8327	101.3131	41.8744	30.8241
522.5	3.2185	101.0262	41.5856	30.8415
527.5	2.6929	100.744	41.2932	30.8567
532.5	2.2605	100.467	40.9881	30.8784
537.5	1.9123	100.1953	40.7032	30.8993
542.5	1.6606	99.9295	40.414	30.9181
547.5	1.5036	99.6697	40.1385	30.938
555.0	0.0	98.2199	39.0225	31.3193
565.0	0.0	136.5882	37.4562	32.4253
575.0	0.0	161.3544	35.8926	33.6972
585.0	0.0	155.83	33.8287	33.6802
595.0	0.0	158.079	32.4447	32.7067
605.0	0.0	135.7374	31.9363	32.0669
615.0	0.0	128.381	31.9991	31.2596
625.0	0.0	124.4358	32.5026	30.0967
635.0	0.0	121.8139	33.1867	28.9589
645.0	0.0	119.4645	33.9037	27.879
655.0	0.0	117.4912	34.6127	26.8762
665.0	0.0	115.6642	35.2633	25.974
675.0	0.3296	114.285	35.9006	25.113
685.0	0.0	113.637	36.5486	24.2899
695.0	0.0	113.2907	37.2366	23.5227
705.0	0.0	112.1874	37.9168	22.7806
715.0	0.2663	111.7342	38.5773	22.0682

Appendix 2B: Range graph values for case 2 (Line 7)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
725.0	4.3506	111.32	39.1717	21.3945
735.0	8.3797	110.9402	39.7559	20.7812
745.0	7.02	110.5982	40.2977	20.2463
755.0	5.0881	110.3452	40.7716	19.7653
765.0	3.7457	110.405	41.2212	19.3187
775.0	2.8067	110.8066	41.6566	18.8886
785.0	2.3973	111.0482	41.8936	18.4032
795.0	2.375	109.8487	42.1094	17.9929
805.0	2.7566	108.55	42.2755	17.6622
815.0	2.5715	110.2618	42.3101	17.4054
825.0	2.0148	129.0553	42.2711	17.4376
835.0	2.1004	146.5402	42.5364	17.7101
845.0	0.0	158.9762	43.0765	18.035
850.0	0.7811	159.7657	43.8663	18.0295

Appendix 2B: Range graph values for case 2 (Line 8)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
0.0	35.0364	199.5097	105.3241	54.1353
2.5	34.8966	199.3556	105.1807	54.1264
7.5	39.8683	200.0187	108.2472	52.4677
12.5	39.5242	199.6338	107.8135	52.4621
17.5	39.2016	199.2481	107.3992	52.4553
22.5	38.8959	198.861	106.9599	52.4451
27.5	38.5983	198.4725	106.5408	52.4339
32.5	38.2442	198.0824	106.1139	52.4224
37.5	37.8397	197.6908	105.6728	52.4084
42.5	37.4372	197.2979	105.2726	52.3899
47.5	37.0381	196.9038	104.8905	52.3757
52.5	36.6438	196.5085	104.4947	52.3804
57.5	36.256	196.1123	104.1101	52.3672
62.5	35.8762	195.7152	103.7132	52.3457
67.5	35.5062	195.3174	103.3641	52.3281
72.5	35.1476	194.9191	102.9861	52.3113
77.5	34.8012	194.5203	102.611	52.2956
82.5	34.468	194.1213	102.2647	52.2741
87.5	34.1488	193.7222	101.912	52.263
92.5	33.8438	193.3231	101.5332	52.2508
97.5	33.5532	192.9241	101.1784	52.2323
102.5	33.2767	192.5252	100.7561	52.2286
107.5	33.0128	192.1265	100.4044	52.2085
112.5	32.7584	191.7281	100.0531	52.1885
117.5	32.43	191.3301	99.6946	52.1658
122.5	32.0722	190.9324	99.3025	52.1565
127.5	31.7181	190.5354	98.908	52.1477
132.5	31.369	190.1388	98.5136	52.1334
137.5	31.026	189.7429	98.1213	52.1232
142.5	30.6891	189.3477	97.742	52.1046
147.5	30.3584	188.9532	97.3505	52.0956
152.5	30.0326	188.5594	96.9677	52.0867
157.5	29.7089	188.1665	96.5872	52.0778
162.5	29.3816	187.7743	96.2088	52.0699
167.5	29.0477	187.383	95.8175	52.0693
172.5	28.7112	186.9927	95.4186	52.0737
177.5	28.3753	186.6037	95.0394	52.0678
182.5	28.0411	186.2168	94.656	52.0659
187.5	27.708	185.8318	94.2676	52.0678

Appendix 2B: Range graph values for case 2 (Line 8)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
192.5	27.3749	185.448	93.8814	52.066
197.5	27.0427	185.0653	93.4928	52.0661
202.5	26.7135	184.6834	93.1215	52.0531
207.5	26.3896	184.3025	92.7402	52.0488
212.5	26.0727	183.9224	92.3612	52.044
217.5	25.764	183.5432	91.9991	52.0337
222.5	25.464	183.1648	91.6214	52.027
227.5	25.1729	182.7873	91.2448	52.0183
232.5	24.8904	182.4107	90.8697	52.0078
237.5	24.616	182.0349	90.463	52.0064
242.5	24.3489	181.66	90.1111	51.9873
247.5	24.0878	181.286	89.7387	51.9752
252.5	23.8321	180.9128	89.3685	51.9619
257.5	23.554	180.5406	88.9939	51.9519
262.5	23.2609	180.1693	88.6385	51.9369
267.5	22.977	179.7989	88.2683	51.9297
272.5	22.7029	179.4297	87.8947	51.9194
277.5	22.4288	179.0616	87.5152	51.913
282.5	22.1372	178.6946	87.1356	51.9072
287.5	21.8503	178.3288	86.7783	51.9053
292.5	21.5685	177.9644	86.4126	51.9003
297.5	21.2922	177.6012	86.0441	51.894
302.5	21.0212	177.2395	85.6874	51.8898
307.5	20.755	176.8793	85.3304	51.8877
312.5	20.4914	176.5206	84.9764	51.8845
317.5	20.1807	176.1633	84.6264	51.8782
322.5	19.8523	175.8073	84.272	51.8669
327.5	19.5318	175.4527	83.9301	51.8563
332.5	19.221	175.0993	83.5907	51.8447
337.5	18.9214	174.7472	83.2346	51.8332
342.5	18.6335	174.3963	82.9021	51.8179
347.5	18.3566	174.0466	82.5558	51.8026
352.5	18.0902	173.6979	82.2246	51.7864
357.5	17.8328	173.3503	81.8809	51.7698
362.5	17.582	173.0037	81.5805	51.7557
367.5	17.2932	172.6582	81.2216	51.7438
372.5	16.9862	172.3138	80.8813	51.7356
377.5	16.6861	171.9704	80.5639	51.7246
382.5	16.3955	171.6281	80.2523	51.7145
387.5	16.1157	171.2868	79.9117	51.7049
392.5	15.8472	170.9466	79.5698	51.6947
397.5	15.5895	170.6075	79.2418	51.6814
402.5	15.3427	170.2696	78.8997	51.6725
407.5	15.1057	169.9328	78.5573	51.6646
412.5	14.8776	169.5973	78.2138	51.6569
417.5	14.6572	169.263	77.8744	51.6504
422.5	14.3679	168.93	77.5472	51.6427
427.5	14.0712	168.5983	77.2154	51.6404

Appendix 2B: Range graph values for case 2 (Line 8)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
432.5	13.7796	168.2684	76.8803	51.6433
437.5	13.4936	167.9499	76.5461	51.653
442.5	13.2134	167.6387	76.2201	51.6565
447.5	12.9393	167.3301	75.9105	51.6476
452.5	12.6705	167.0235	75.5619	51.6581
457.5	12.4065	166.7188	75.2298	51.668
462.5	12.1458	166.4163	74.9148	51.6688
467.5	11.8867	166.116	74.5905	51.6826
472.5	11.6243	165.8178	74.2826	51.6817
477.5	11.311	165.5218	73.9714	51.6806
482.5	10.999	165.2281	73.674	51.6792
487.5	10.6907	164.9368	73.3674	51.6904
492.5	10.386	164.6479	73.0703	51.6903
497.5	10.0848	164.3615	72.7706	51.6908
502.5	9.7874	164.0777	72.4724	51.6945
507.5	9.4952	163.7967	72.157	51.7025
512.5	9.2094	163.5187	71.8664	51.7103
517.5	8.9311	163.2438	71.5949	51.7147
522.5	8.6616	162.9721	71.3109	51.7137
527.5	8.402	162.7038	71.0217	51.7221
532.5	8.1531	162.439	70.7337	51.7306
537.5	7.9153	162.1779	70.4524	51.7387
542.5	7.658	161.9205	70.1787	51.7435
547.5	7.4019	161.6669	69.8984	51.7538
555.0	6.1451	160.2253	68.3925	51.8635
565.0	0.0	157.7612	66.0468	52.1347
575.0	0.0	155.6172	63.8523	52.2388
585.0	0.0	153.8002	61.9625	52.4167
595.0	0.0	152.302	60.4772	52.5287
605.0	0.0	151.1108	59.3823	53.13
615.0	0.0	150.213	57.7708	53.2851
625.0	0.0	149.5616	57.0129	53.1215
635.0	0.0	149.1019	56.5954	52.8265
645.0	0.0	148.8647	56.6975	52.043
655.0	2.6149	148.8111	57.0287	50.9056
665.0	4.3615	148.7375	57.4812	49.6561
675.0	6.3141	147.1797	58.113	48.4469
685.0	8.3956	146.6179	58.8561	47.4373
695.0	10.4699	146.4029	59.6648	46.512
705.0	12.0078	146.2723	60.5052	45.6562
715.0	13.0607	146.1948	61.3703	44.8275

Appendix 2B: Range graph values for case 2 (Line 8)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
725.0	12.908	146.1615	62.1456	44.0021
735.0	12.1296	146.103	62.9694	43.1347
745.0	11.4633	145.7403	63.7332	42.1779
755.0	10.9009	144.2498	64.3879	41.0829
765.0	10.4341	142.1655	64.9748	39.8137
775.0	10.0551	139.9161	65.5027	38.4762
785.0	9.7464	137.6548	65.9056	37.2473
795.0	9.4291	135.8616	66.36	36.3123
805.0	8.9675	140.9605	66.6363	35.595
815.0	8.5618	145.6552	66.6216	35.0291
825.0	8.2759	154.2205	66.1839	34.5914
835.0	8.1147	159.6449	65.3896	34.2441
845.0	8.0777	164.3088	65.0292	34.1344
850.0	8.1414	164.372	65.092	34.1339

Appendix 2C: Range graph values for case 3 (Line 1)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
0.0	85.419	421.8659	241.1305	114.7606
2.5	92.2169	426.5235	246.7789	114.057
7.5	52.3314	343.8927	182.4374	101.1006
12.5	50.4456	342.0177	180.3622	101.141
17.5	48.6467	340.1213	178.2919	101.1285
22.5	46.9322	338.3251	176.2766	101.0849
27.5	45.3003	336.6616	174.3381	101.0391
32.5	43.7449	334.9718	172.7863	101.1506
37.5	42.2641	333.2569	170.9406	101.0546
42.5	40.8482	331.514	169.0753	100.9453
47.5	39.49	329.7444	167.2358	100.8487
55.0	38.5931	328.5317	166.0433	100.8106
65.0	38.173	327.8685	165.383	100.8214
75.0	37.805	327.1742	164.4926	100.7273
85.0	37.4198	326.4518	163.9766	100.8707
95.0	36.9339	325.7022	163.2819	100.8864
105.0	36.4948	324.9272	162.486	100.7488
115.0	36.1039	324.1277	161.7615	100.6782
125.0	35.5948	323.3047	161.0628	100.6257
135.0	34.951	322.4621	160.3706	100.5586
145.0	34.3313	321.6011	159.6981	100.4682
155.0	33.7639	320.7242	158.8692	100.3266
165.0	33.2567	319.8345	158.2098	100.239
175.0	32.8045	318.9366	157.5414	100.166
185.0	32.398	318.036	156.8493	100.1207
195.0	32.0268	317.1411	156.1125	100.0899
205.0	31.6772	316.3681	155.3698	100.0768
215.0	31.2924	315.88	154.6905	100.0282
225.0	30.8355	315.3774	154.0147	100.0093
235.0	30.365	314.8565	153.3347	100.0121
245.0	29.8848	314.3142	152.6596	100.0138
255.0	29.379	313.8226	151.956	99.9806
265.0	28.8377	313.3949	151.2343	99.9406
275.0	28.2957	312.9577	150.5534	99.9606

Appendix 2C: Range graph values for case 3 (Line 1)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
285.0	27.7858	312.5073	149.8729	99.9619
295.0	27.2648	312.0404	149.201	99.9439
305.0	26.7762	311.554	148.5642	99.9348
315.0	26.3383	311.0447	148.034	100.0129
325.0	25.9457	310.5108	147.3887	99.9832
335.0	25.5913	309.9485	146.7741	99.9688
345.0	25.2402	309.3582	146.1749	99.9483
355.0	24.9007	308.7368	145.5676	99.932
365.0	24.6019	308.0834	144.9345	99.8772
375.0	24.2112	307.3992	144.3892	99.8166
385.0	23.7634	306.6849	143.7982	99.7701
395.0	23.1633	305.9417	143.1869	99.7575
405.0	22.6252	305.1719	142.6024	99.647
415.0	22.1247	304.3785	141.9892	99.6248
425.0	21.6632	303.5651	141.3734	99.5891
435.0	21.2522	302.7362	140.756	99.5749
445.0	20.8844	301.8965	140.13	99.5544
455.0	20.5505	301.0518	139.5106	99.526
465.0	20.2359	300.3081	138.8884	99.4946
475.0	19.9272	299.7704	138.2493	99.4698
485.0	19.5328	299.2631	137.6232	99.4242
495.0	18.9412	298.7586	137.0472	99.384
505.0	18.3331	298.2476	136.4642	99.3706
515.0	17.7543	297.7657	135.9318	99.3076
525.0	17.2067	297.3259	135.3683	99.281
535.0	16.6996	296.8632	134.8309	99.2345
545.0	16.2008	296.3748	134.2697	99.1963
552.5	15.2966	295.3742	133.2212	99.1285
557.5	13.8611	293.9082	131.4936	99.5022
562.5	12.6371	292.4583	130.0108	99.8025
567.5	11.5754	291.0302	128.9297	99.9022
572.5	10.6685	289.6451	127.7664	99.9983
577.5	9.7307	288.2753	126.4853	100.0171
582.5	6.6	286.9204	125.1392	99.9499
587.5	3.6506	285.5805	123.7656	99.8862
592.5	3.0959	284.256	122.4813	99.8136
597.5	3.2834	282.948	121.1624	99.6711
602.5	3.3308	281.6579	119.8258	99.5535
607.5	2.9013	280.3884	118.4475	99.4967
612.5	1.739	279.1425	117.1006	99.5353
617.5	1.2373	277.9227	115.982	99.6286
622.5	1.5503	276.7325	115.0072	99.7457
627.5	1.5677	275.5758	114.1259	99.8553
632.5	1.156	274.4578	113.3607	99.902

Appendix 2C: Range graph values for case 3 (Line 1)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
637.5	0.7159	273.3822	112.5624	100.0266
642.5	0.3806	272.3546	111.4563	100.2401
647.5	0.0	271.9662	110.5914	100.4277
652.5	0.0	270.4628	109.7793	100.5325
657.5	0.0	269.6074	108.9967	100.594
662.5	0.0	268.817	108.2885	100.6136
667.5	0.0	268.0934	107.6721	100.6187
672.5	0.0	267.4341	107.2509	100.7144
677.5	0.0	266.8333	107.167	100.8971
682.5	0.0	269.5619	107.1501	100.9049
687.5	0.0	275.2263	107.3639	100.815
692.5	0.0	280.5613	106.8427	99.888
697.5	0.0	284.8906	106.761	101.4705
702.5	0.0	288.6729	105.558	100.9496
707.5	0.0	292.0317	104.7829	101.5314
712.5	0.0	294.8484	104.3044	103.1186
717.5	0.0	296.9784	102.9373	103.6304
722.5	0.0	298.2755	100.7253	103.1905
727.5	0.0	298.7469	101.105	103.9446
732.5	0.0	298.3111	101.3121	103.7714
737.5	0.0	295.2298	100.8361	103.4834
742.5	0.0	291.8421	98.7634	102.9806
747.5	0.0	288.6704	98.5272	102.8496
752.5	0.0	286.7928	98.4524	102.5792
757.5	0.0	292.0273	98.567	102.2936
762.5	0.0	297.1736	99.1205	101.5904
767.5	0.0	300.0203	99.2185	101.1713
772.5	0.0	301.0741	99.3294	100.6632
777.5	0.0	301.4705	99.4691	100.1233
782.5	0.0	301.7639	99.6175	99.5216
787.5	0.0	303.5187	100.1174	99.091
792.5	0.0	306.0685	100.3675	98.8135
797.5	0.0	307.5752	100.3017	98.6843
800.0	0.0324	307.6115	100.3342	98.6805

Appendix 2C: Range graph values for case 3 (Line 2)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
0.0	51.6288	223.1568	116.5132	46.336
2.5	50.6513	221.8619	115.3929	46.3125
7.5	50.4875	246.9563	130.0191	61.4498
12.5	48.4347	245.9449	127.9424	61.5422
17.5	46.551	243.1059	125.8663	61.5957
22.5	44.805	238.6905	123.8093	61.5209
27.5	43.1719	232.8915	121.7079	61.4769
32.5	41.6379	228.7253	119.6129	61.3514
37.5	40.1949	226.7709	117.5272	61.189
42.5	38.8327	224.8073	115.3962	61.185
47.5	37.5211	222.8353	113.3483	61.0225
55.0	36.6061	221.4947	111.9257	60.9842
65.0	36.1277	220.7705	111.1369	60.9652
75.0	35.5968	220.0221	110.3454	60.9307
85.0	35.0689	219.2516	109.5398	60.8831
95.0	34.5428	218.4619	108.7608	60.8645
105.0	34.0401	217.6572	108.0	60.8444
115.0	33.5717	216.8449	107.2558	60.8182
125.0	33.0968	216.0359	106.5654	60.8162
135.0	32.6671	215.2444	105.8829	60.7706
145.0	32.2818	214.487	105.1864	60.7311
155.0	31.9025	213.7692	104.3624	60.6319
165.0	31.3681	213.0788	103.6842	60.6609
175.0	30.8037	212.4018	103.0288	60.711
185.0	30.3159	211.7285	102.3928	60.7797
195.0	29.9372	211.0513	101.7535	60.8379
205.0	29.6352	210.3665	101.0194	60.8568
215.0	29.0105	209.6738	100.3379	60.8612
225.0	28.2933	209.0561	99.516	60.8586
235.0	27.5807	208.4203	98.7726	60.8319
245.0	26.8498	207.7657	98.0867	60.8232
255.0	26.1303	207.0921	97.4373	60.8374
265.0	25.3155	206.4	96.7239	60.8008
275.0	24.486	205.6902	96.0246	60.7937
285.0	23.7915	204.9641	95.283	60.7177
295.0	23.2369	204.3408	94.553	60.6442
305.0	22.7902	203.7373	93.8221	60.5783
315.0	22.3789	203.1253	93.0842	60.5284
325.0	21.909	202.5005	92.3345	60.4855
335.0	21.3903	201.8593	91.6277	60.4539

Appendix 2C: Range graph values for case 3 (Line 2)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
345.0	20.9187	201.1983	91.0284	60.5539
355.0	20.5404	200.5159	90.3481	60.5264
365.0	20.1388	199.8106	89.557	60.3396
375.0	19.8606	199.0823	88.9801	60.3902
385.0	19.6311	198.3309	88.2852	60.2658
395.0	19.047	197.5568	87.6646	60.2287
405.0	18.4642	196.7615	87.08	60.2305
415.0	17.7466	195.9472	86.4318	60.2396
425.0	16.855	195.1548	85.6988	60.2354
435.0	16.0818	194.5122	85.0192	60.2199
445.0	15.4139	193.8697	84.5151	60.1182
455.0	14.7856	193.2321	83.9596	60.0803
465.0	14.1227	192.6111	83.3348	60.087
475.0	13.4469	192.0251	82.7265	60.0697
485.0	12.806	191.4769	82.0945	60.1528
495.0	12.26	190.9472	81.444	60.1679
505.0	11.7806	190.4231	80.8362	60.1588
515.0	11.3494	189.8967	80.2253	60.1273
525.0	10.8825	189.3644	79.6366	60.1316
535.0	10.396	188.8234	78.9614	60.205
545.0	9.9359	188.2729	78.4693	60.2236
552.5	9.2275	187.1712	77.438	60.4396
557.5	0.0	185.5783	75.9927	61.4492
562.5	0.0	184.0308	74.9745	61.772
567.5	0.0	182.5337	73.7268	61.8061
572.5	0.0	181.6326	72.3636	61.7432
577.5	0.0	182.371	71.0953	61.6836
582.5	0.0	178.4057	69.8455	61.5043
587.5	0.0	177.1676	68.5701	61.3935
592.5	0.0	176.0063	67.5093	61.2242
597.5	0.0	174.9258	66.4698	61.1428
602.5	0.0	173.9285	65.3485	61.2403
607.5	0.0	173.0143	64.5827	61.4241
612.5	0.0	172.1824	64.0095	61.6369
617.5	0.0	171.4318	63.6306	61.8585
622.5	0.0	170.7599	63.5577	62.1188
627.5	0.0	170.1638	63.2782	62.8204
632.5	0.0	170.1166	62.3738	63.3087
637.5	0.0	172.0745	61.2634	63.8561

Appendix 2C: Range graph values for case 3 (Line 2)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
642.5	0.0	175.6512	60.112	64.0754
647.5	0.0	186.8161	58.72	63.8321
652.5	0.0	203.0365	57.6684	63.7004
657.5	0.0	199.3757	57.1385	63.2049
662.5	0.0	177.3849	56.6258	62.7322
667.5	0.0	169.5995	56.6169	62.2314
672.5	0.0	167.3775	56.7315	61.6962
677.5	0.0	167.2579	56.8711	61.098
682.5	0.0	167.1771	56.9936	60.4792
687.5	0.1619	166.7716	57.1892	59.7995
692.5	0.7046	165.8083	57.396	59.1105
697.5	1.4348	164.6792	57.6662	58.4896
702.5	2.2298	189.2172	58.1832	58.2306
707.5	2.0955	210.132	58.6463	57.9611
712.5	0.0	224.3263	59.057	57.6247
717.5	0.0	232.9568	59.4099	57.1814
722.5	0.0	238.4888	59.7206	56.6287
727.5	0.0	241.4859	59.9966	55.9394
732.5	0.0	239.9955	60.2336	55.1311
737.5	0.0	237.8536	60.4935	54.2906
742.5	0.0	236.7584	60.7381	53.5167
747.5	0.0	236.9598	60.9572	52.7672
752.5	0.0	247.2251	61.2091	52.2453
757.5	0.0	256.7298	61.5055	51.7271
762.5	0.0	264.0517	61.5658	51.3505
767.5	0.0	268.7783	61.5109	51.1019
772.5	0.0	270.4946	61.792	50.7569
777.5	0.0	269.461	62.1829	50.401
782.5	0.0	267.3132	62.3805	50.0574
787.5	0.0	265.3679	62.2932	49.8082
792.5	0.0	265.7637	62.1266	49.698
797.5	0.0	266.7509	62.0719	49.6725
800.0	0.035	266.7859	62.1052	49.6704

Appendix 2C: Range graph values for case 3 (Line 3)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
0.0	68.7496	346.5039	200.6997	92.7128
2.5	85.2278	358.7808	214.9669	91.2577
7.5	52.1806	287.7038	160.3955	79.2106
12.5	50.1857	285.8989	158.396	79.2594
17.5	48.3048	284.1793	156.3976	79.2458
22.5	46.5076	282.4237	154.4276	79.2462
27.5	44.749	280.6313	152.4263	79.2552
32.5	42.9938	278.8011	150.4548	79.2047
37.5	41.2376	276.931	148.5138	79.1217
42.5	39.4761	275.0256	146.5712	78.973
47.5	37.6921	273.0846	144.6255	78.8854
55.0	36.458	271.7492	143.2945	78.8486
65.0	35.8611	271.0103	142.4915	78.7804
75.0	35.3332	270.2333	141.791	78.784
85.0	34.857	269.4226	141.0624	78.7252
95.0	34.4086	268.5832	140.3877	78.6832
105.0	33.9575	267.7209	139.7256	78.6328
115.0	33.4863	266.8427	139.049	78.5922
125.0	33.0045	265.959	138.372	78.5711
135.0	32.5405	265.1387	137.7015	78.5729
145.0	32.1202	264.5023	137.0284	78.5838
155.0	31.756	263.9293	136.3209	78.5703
165.0	31.4516	263.3687	135.6017	78.5416
175.0	31.194	262.8036	134.8977	78.5399
185.0	30.8747	262.2252	134.2201	78.5512
195.0	30.5198	261.6292	133.5827	78.5795
205.0	30.2129	261.0122	132.8997	78.5711
215.0	29.8113	260.3722	132.1979	78.5568
225.0	29.3034	259.7087	131.484	78.5406
235.0	28.7673	259.0223	130.782	78.5238
245.0	28.2268	258.3144	130.0885	78.5142
255.0	27.6975	257.5871	129.397	78.4936
265.0	27.1868	256.8434	128.6997	78.4619
275.0	26.7086	256.088	127.9959	78.4222
285.0	26.2741	255.3266	127.2677	78.4415
295.0	25.8979	254.5677	126.5943	78.4053
305.0	25.5737	253.8249	125.9174	78.3604
315.0	25.2732	253.1145	125.2433	78.2743
325.0	25.0315	252.4444	124.4966	78.2058
335.0	24.8486	251.8063	123.7999	78.181
345.0	24.3734	251.186	123.1174	78.1605

Appendix 2C: Range graph values for case 3 (Line 3)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
355.0	23.8367	250.5717	122.4672	78.1504
365.0	23.3486	249.9545	121.8646	78.1337
375.0	22.6962	249.3281	121.2745	78.1035
385.0	22.0691	248.689	120.7094	78.0704
395.0	21.4698	248.0366	120.0638	78.0644
405.0	20.8834	247.3704	119.4846	78.0211
415.0	20.2804	246.6927	118.9369	77.9502
425.0	19.6464	246.0074	118.491	77.9369
435.0	18.9899	245.3206	117.9103	77.9094
445.0	18.3211	244.6419	117.3131	77.8861
455.0	17.6157	243.9859	116.712	77.8692
465.0	16.8932	243.3678	116.097	77.8548
475.0	16.1711	242.7901	115.4584	77.8274
485.0	15.4586	242.2395	114.8012	77.8017
495.0	14.7586	241.7005	114.1347	77.789
505.0	14.1009	241.1625	113.4783	77.7849
515.0	13.4959	240.6176	112.8559	77.7923
525.0	12.9458	240.0611	112.2697	77.7954
535.0	12.4139	239.4888	111.6943	77.8064
545.0	11.7054	238.899	111.1053	77.8392
552.5	10.4807	237.7242	110.1146	77.8961
557.5	8.5257	236.0122	108.5377	78.2979
562.5	7.1848	234.3322	107.2031	78.5541
567.5	5.9501	232.687	105.9726	78.5519
572.5	4.7664	231.0795	104.6378	78.519
577.5	3.5838	229.513	103.2948	78.4103
582.5	2.6467	227.9896	101.8173	78.2053
587.5	1.973	226.5127	100.2932	78.0647
592.5	1.5397	225.0849	98.5457	77.9235
597.5	1.2996	223.71	97.2526	77.8647
602.5	1.0168	222.3901	96.0203	77.7992
607.5	0.673	221.1284	94.8855	77.7662
612.5	0.3809	219.9256	93.663	77.7616
617.5	0.0	218.7832	92.5009	77.771
622.5	0.0	217.7019	91.3965	77.8038
627.5	0.0	216.7021	90.3788	77.8312
632.5	0.0	215.9128	89.4552	77.7917
637.5	0.0	215.1743	88.7421	77.6721
642.5	0.0	214.4838	88.0485	77.6278
647.5	0.0	213.8379	87.4064	77.7135
652.5	0.0	213.2334	87.2734	77.9239
657.5	0.0	212.6674	87.0261	78.2266
662.5	0.0	212.135	87.1374	78.4327
667.5	0.0	211.6324	86.5866	78.1974
672.5	0.0	211.1581	86.8373	78.8593
677.5	0.0	210.7083	84.9694	79.2959

Appendix 2C: Range graph values for case 3 (Line 3)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
682.5	0.0	212.0266	85.601	80.1535
687.5	0.0	213.2959	83.2456	80.3555
692.5	0.0	212.9862	81.8792	80.6463
697.5	0.0	211.5059	82.0472	80.9078
702.5	0.0	213.0655	81.927	80.899
707.5	0.0	217.4169	81.8862	80.8341
712.5	0.0	219.5413	81.8843	80.5931
717.5	0.0	223.3331	82.139	80.3068
722.5	0.0	226.8882	82.1541	79.8978
727.5	0.0	229.2446	82.2136	79.4194
732.5	0.0	230.752	82.2067	78.8558
737.5	0.0	232.0368	81.5486	77.7106
742.5	0.0	233.4379	81.3901	77.1529
747.5	0.0	235.0604	81.3273	76.6092
752.5	0.0	236.7424	81.4091	75.9748
757.5	0.0	238.8198	81.6198	75.3523
762.5	0.0	241.477	81.5648	74.9449
767.5	0.0	244.3047	81.8319	74.2895
772.5	0.0	246.5618	82.0853	73.711
777.5	0.0	247.5862	82.3277	73.1927
782.5	0.0	247.4819	82.405	72.784
787.5	0.0	247.7207	82.2208	72.4713
792.5	0.0	247.7648	81.9556	72.2531
797.5	0.0	248.1673	81.8513	72.1465
800.0	0.0353	248.202	81.8841	72.1435

Appendix 2C: Range graph values for case 3 (Line 4)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
0.0	54.6625	190.6365	114.3943	42.4197
2.5	53.2871	190.5258	113.9475	43.2716
7.5	54.226	224.5425	127.8853	55.8099
12.5	52.0393	222.6606	125.7615	55.8566
17.5	50.0289	220.7692	123.6435	55.8655
22.5	48.1694	218.8688	121.5409	55.8353
27.5	46.4324	216.9538	119.4625	55.7633
32.5	44.7868	215.0216	117.3857	55.6751
37.5	43.0092	213.0739	115.3196	55.5618
42.5	41.077	211.1096	113.2634	55.4602
47.5	39.1948	209.1267	111.2246	55.3857
55.0	37.9354	207.7737	109.8623	55.3698
65.0	37.3105	207.0342	109.1159	55.3868
75.0	36.7416	206.2617	108.3856	55.3956
85.0	36.2202	205.4599	107.6948	55.3854
95.0	35.7363	204.6321	107.0022	55.3677
105.0	35.2781	203.7852	106.2854	55.3512
115.0	34.8389	202.9252	105.5341	55.3576
125.0	34.4193	202.0604	104.8048	55.3565
135.0	34.0211	201.2095	104.053	55.3186
145.0	33.6416	200.4005	103.2725	55.2534
155.0	33.2761	199.6451	102.5183	55.2133
165.0	32.8128	198.9264	101.8443	55.2388
175.0	32.1839	198.2248	101.1846	55.2926
185.0	31.5067	197.5265	100.5327	55.3503
195.0	30.8284	196.8251	99.834	55.388
205.0	30.1545	196.1169	99.1352	55.41
215.0	29.4789	195.5061	98.4188	55.3907
225.0	28.813	194.9425	97.6984	55.3557
235.0	28.1818	194.3586	96.9911	55.3266
245.0	27.5986	193.7533	96.2911	55.3092
255.0	27.062	193.1263	95.5832	55.2925
265.0	26.5739	192.4774	94.8671	55.2739
275.0	26.1218	191.8069	94.1555	55.2467

Appendix 2C: Range graph values for case 3 (Line 4)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
285.0	25.4833	191.1141	93.4448	55.2201
295.0	24.8066	190.3993	92.7329	55.2017
305.0	24.1702	189.663	92.0014	55.1559
315.0	23.5416	188.9074	91.2555	55.0975
325.0	22.9328	188.1351	90.5005	55.0633
335.0	22.3775	187.351	89.7836	55.0447
345.0	21.8881	186.5557	89.1133	55.0297
355.0	21.4577	185.7502	88.4638	55.0135
365.0	21.0693	185.0461	87.7716	54.9946
375.0	20.7082	184.357	87.0615	54.9644
385.0	20.3491	183.6514	86.3577	54.9208
395.0	19.8009	182.9288	85.7314	54.8727
405.0	19.1038	182.1894	85.1563	54.8311
415.0	18.2728	181.4355	84.567	54.7994
425.0	17.4377	180.7543	83.9645	54.7731
435.0	16.6158	180.1043	83.3374	54.7591
445.0	15.8402	179.449	82.701	54.7443
455.0	15.1056	178.7885	82.0825	54.7557
465.0	14.3515	178.123	81.4584	54.7354
475.0	13.5628	177.455	80.8322	54.7398
485.0	12.8689	176.7887	80.2214	54.7389
495.0	12.2146	176.1412	79.6039	54.7484
505.0	11.6002	175.6099	78.9818	54.752
515.0	11.0199	175.0715	78.377	54.7321
525.0	10.4828	174.5136	77.7456	54.721
535.0	9.9997	173.9337	77.088	54.7676
545.0	9.5815	173.3307	76.5149	54.761
552.5	8.9592	172.1583	75.5495	54.8506
557.5	0.0	170.6686	73.973	55.9022
562.5	0.0	169.244	72.8678	56.186
567.5	0.0	167.8771	71.5243	56.0692

Appendix 2C: Range graph values for case 3 (Line 4)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
572.5	0.0	166.5662	70.0709	55.7761
577.5	0.0	165.3117	68.7416	55.6545
582.5	0.0	164.116	67.4741	55.5318
587.5	0.0	162.9806	66.2184	55.4104
592.5	0.0	161.908	65.1201	55.4395
597.5	0.0	160.9009	64.2848	55.5744
602.5	0.0	159.9596	63.2069	55.5681
607.5	0.0	159.084	62.4749	55.6611
612.5	0.0	158.2731	61.7396	55.7486
617.5	0.0	157.5249	61.1296	55.8917
622.5	0.0	156.836	60.8051	56.1681
627.5	0.0	156.4095	60.8428	56.6475
632.5	0.0	155.6202	59.1926	57.1637
637.5	0.0	155.4358	58.3351	57.8101
642.5	0.0	162.0064	57.2156	58.0595
647.5	0.0	171.2871	55.9365	57.9359
652.5	0.0	187.7861	55.44	58.0628
657.5	0.0	183.1452	54.828	57.6356
662.5	0.0	155.0661	54.3832	56.7699
667.5	0.0	152.7739	54.0891	55.999
672.5	0.0	152.5097	54.2146	55.5055
677.5	0.0	152.2719	54.3978	54.91
682.5	0.0	152.0791	54.6675	54.2594
687.5	0.0512	151.3473	55.1274	53.5546
692.5	0.4929	150.3049	55.4874	52.8523
697.5	0.4608	149.5109	55.9068	52.2694
702.5	0.0	163.1111	56.4458	51.9755
707.5	0.0	176.9715	56.9249	51.7102
712.5	0.0	185.5405	57.3892	51.4276
717.5	0.0	189.3238	57.8285	51.07
722.5	0.0	189.0786	58.2129	50.6105
727.5	0.0	187.0339	58.5789	50.1032
732.5	0.0	186.8254	58.9582	49.598
737.5	0.0	191.8987	59.4106	49.2734
742.5	0.0	200.1214	59.8871	48.9889
747.5	0.0	205.8913	60.1292	48.8684
752.5	0.0	211.4889	60.4585	48.6692
757.5	0.0	216.3887	60.9381	48.3689
762.5	0.0	221.1323	61.4467	48.1096
767.5	0.0	225.1618	61.9123	47.7967
772.5	0.0	225.9857	62.3464	47.4149
777.5	0.0	225.039	62.6355	47.0441
782.5	0.0	224.9326	62.695	46.7759
787.5	0.0	224.9573	62.504	46.6378
792.5	0.0	226.811	62.3245	46.5448
797.5	0.0	227.7027	62.2491	46.5234
800.0	0.0132	227.7154	62.2611	46.5227

Appendix 2C: Range graph values for case 3 (Line 5)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
0.0	85.5826	311.293	191.0684	74.7753
2.5	98.1502	321.7553	202.5392	74.0909
7.5	56.1561	251.4734	145.4353	64.8939
12.5	53.5345	249.5402	143.3747	64.9021
17.5	50.9834	247.5947	141.3083	64.9319
22.5	48.5136	245.6375	139.1964	64.9846
27.5	46.1326	243.669	137.1625	64.9717
32.5	43.8445	241.6868	135.1604	64.928
37.5	41.6492	239.6937	133.2232	64.845
42.5	39.5024	237.693	131.354	64.7476
47.5	37.4033	235.6862	129.504	64.7095
55.0	36.0098	234.3216	128.1798	64.6945
65.0	35.3477	233.6001	127.415	64.6828
75.0	34.7763	232.8737	126.642	64.6735
85.0	34.2956	232.1453	125.8723	64.655
95.0	33.9061	231.4198	125.1427	64.627
105.0	33.6062	230.7069	124.4003	64.6391
115.0	33.3624	230.0089	123.6847	64.6011
125.0	33.1209	229.314	122.9108	64.52
135.0	32.775	228.6186	122.181	64.5019
145.0	32.3098	227.9212	121.4545	64.4833
155.0	31.8855	227.2205	120.7512	64.4792
165.0	31.5107	226.5158	120.0472	64.4695
175.0	31.1833	225.8064	119.3513	64.4407
185.0	30.8898	225.0918	118.6781	64.4202
195.0	30.6134	224.3717	118.0188	64.407
205.0	30.3411	223.6463	117.3692	64.4119
215.0	30.0756	222.9159	116.6191	64.3865
225.0	29.8135	222.1815	115.9365	64.3557
235.0	29.5219	221.4817	115.2522	64.3526
245.0	29.1705	220.8274	114.526	64.312
255.0	28.8111	220.1686	113.8113	64.2568
265.0	28.4814	219.5054	113.094	64.2258
275.0	28.1886	218.8382	112.3707	64.1731
285.0	27.9209	218.1675	111.6413	64.2076
295.0	27.6435	217.494	110.9307	64.2024
305.0	27.1539	216.819	110.2241	64.2721
315.0	26.4223	216.144	109.5442	64.2798
325.0	25.7136	215.473	108.9016	64.2539
335.0	25.0616	214.8158	108.1965	64.232

Appendix 2C: Range graph values for case 3 (Line 5)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
345.0	24.4726	214.1756	107.5987	64.2033
355.0	23.9425	213.5415	107.0482	64.1101
365.0	23.4577	212.9081	106.4532	64.1233
375.0	22.983	212.2736	105.8462	64.1055
385.0	22.4381	211.637	105.2136	64.0716
395.0	21.7936	210.9976	104.568	64.0488
405.0	21.1097	210.3552	103.9252	64.0226
415.0	20.4226	209.7099	103.2883	63.9996
425.0	19.7023	209.0617	102.6642	63.9732
435.0	19.022	208.4108	102.0139	63.9415
445.0	18.3461	207.7582	101.3657	63.9258
455.0	17.5091	207.1044	100.7124	63.9056
465.0	16.2308	206.4505	100.0523	63.8865
475.0	14.9677	205.7973	99.3925	63.8938
485.0	13.7937	205.146	98.7746	63.8626
495.0	12.7151	204.4977	98.1857	63.826
505.0	11.74	203.8535	97.6031	63.7828
515.0	10.8858	203.2143	96.9936	63.7568
525.0	10.1345	202.58	96.3674	63.7582
535.0	9.4733	201.9502	95.7232	63.7741
545.0	8.9097	201.3244	95.1432	63.7536
552.5	8.093	200.1234	94.1406	63.6983
557.5	6.8807	198.3867	92.451	64.2105
562.5	3.4513	196.7789	91.0109	64.5053
567.5	3.3345	195.2143	89.7625	64.4504
572.5	2.2124	193.6934	88.4447	64.3453
577.5	1.1528	192.2179	87.1336	64.1792
582.5	0.9103	190.79	85.7641	64.0694
587.5	1.0685	189.4121	84.3952	63.992
592.5	0.7969	188.0873	83.1537	63.986
597.5	0.0	186.8185	81.952	63.9761
602.5	0.0	185.6086	80.7331	63.9874
607.5	0.0	184.4601	79.5409	64.0119

Appendix 2C: Range graph values for case 3 (Line 5)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
612.5	0.0	183.3753	78.4511	64.0097
617.5	0.0	182.3564	77.502	63.9532
622.5	0.0	181.405	76.6229	63.9165
627.5	0.0	180.5227	75.7232	63.9549
632.5	0.0	179.7112	74.8824	64.0264
637.5	0.0	178.9751	74.1746	64.0873
642.5	0.0	178.3225	73.6078	64.1307
647.5	0.0	177.7549	73.2713	64.1892
652.5	0.0	177.2609	73.0058	64.2543
657.5	0.0	176.8326	72.2429	64.7593
662.5	0.0	176.4639	71.6539	65.2746
667.5	0.0	176.1447	70.1726	65.8273
672.5	0.0	175.8738	68.7582	65.9998
677.5	0.0	175.6502	68.0615	65.8297
682.5	0.0	175.4668	67.8708	65.8589
687.5	0.0	175.3164	67.8434	65.7108
692.5	0.0	175.2074	67.9278	65.4137
697.5	0.0	175.1362	68.0551	64.9875
702.5	0.0	175.0939	68.1948	64.4918
707.5	0.0	175.0815	68.35	63.9567
712.5	0.0	175.1079	68.5023	63.3666
717.5	0.0	174.7234	68.7154	62.805
722.5	0.1583	179.3233	68.9281	62.1819
727.5	0.5919	184.4688	69.1336	61.4716
732.5	1.2583	187.8857	69.2359	60.6465
737.5	2.0566	190.538	69.1239	59.6371
742.5	2.8978	192.987	69.2269	58.8863
747.5	3.7715	195.8197	69.3084	58.0998
752.5	4.6743	199.2413	69.2829	57.3176
757.5	2.7008	203.4154	69.2294	56.6311
762.5	0.664	207.8667	69.1302	56.0739
767.5	0.0	211.9962	69.1836	55.6449
772.5	0.0	214.4162	69.393	55.2807
777.5	0.0	215.0635	69.5373	54.9759
782.5	0.0	215.3682	69.2729	54.6159
787.5	0.0	215.7341	68.9464	54.3892
792.5	0.0	216.2113	68.7515	54.3453
797.5	0.0	219.4325	68.7131	54.2983
800.0	0.0349	219.4679	68.7461	54.2959

Appendix 2C: Range graph values for case 3 (Line 6)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
0.0	54.5653	242.2298	141.5497	62.1574
2.5	53.4386	241.1501	140.3948	62.1788
7.5	57.155	265.8892	153.1861	69.2758
12.5	54.8848	263.9454	151.0632	69.3109
17.5	52.69	261.9986	148.9189	69.3552
22.5	50.5671	260.0464	146.7974	69.3565
27.5	48.5093	258.0867	144.7172	69.3118
32.5	46.5064	256.1181	142.6662	69.2531
37.5	44.5514	254.1404	140.6573	69.1693
42.5	42.6396	252.1542	138.7004	69.0687
47.5	40.7699	250.1614	136.7504	68.9683
55.0	39.509	248.8051	135.4131	68.9164
65.0	38.8589	248.0786	134.6775	68.9057
75.0	38.2488	247.3427	133.9335	68.9041
85.0	37.6785	246.5993	133.1979	68.9037
95.0	37.1413	245.8496	132.4741	68.8733
105.0	36.6162	245.0949	131.7554	68.8335
115.0	36.0827	244.3371	131.0388	68.7902
125.0	35.551	243.5783	130.3225	68.7588
135.0	35.0357	242.8223	129.6344	68.737
145.0	34.5441	242.076	128.9125	68.7053
155.0	34.0832	241.3477	128.2373	68.6792
165.0	33.6576	240.6346	127.5637	68.6742
175.0	33.2585	239.9301	126.9134	68.6647
185.0	32.8166	239.2301	126.2073	68.6459
195.0	32.2668	238.5327	125.533	68.6153
205.0	31.7315	237.8369	124.9254	68.5883
215.0	31.24	237.1414	124.2693	68.5651
225.0	30.8019	236.4465	123.5701	68.5387
235.0	30.4277	235.7522	122.8444	68.5105
245.0	30.1199	235.0594	122.1027	68.5169

Appendix 2C: Range graph values for case 3 (Line 6)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
255.0	29.8797	234.3692	121.3829	68.514
265.0	29.7027	233.6832	120.6936	68.5107
275.0	29.573	233.0027	119.9943	68.5306
285.0	29.4536	232.3286	119.3139	68.5344
295.0	29.1685	231.6606	118.6185	68.5269
305.0	28.4861	230.9975	117.9504	68.5241
315.0	27.8295	230.338	117.3013	68.5249
325.0	27.204	229.6806	116.6544	68.5073
335.0	26.6105	229.0241	116.015	68.4898
345.0	26.0487	228.3674	115.3535	68.4783
355.0	25.5135	227.7099	114.6683	68.4761
365.0	24.9841	227.0517	113.9874	68.4663
375.0	24.3367	226.3926	113.3123	68.4768
385.0	23.6852	225.7323	112.6705	68.4502
395.0	23.0781	225.0704	112.0478	68.4227
405.0	22.4511	224.4071	111.4241	68.3999
415.0	21.8178	223.7429	110.9221	68.3517
425.0	21.1679	223.0792	110.3023	68.3366
435.0	20.4112	222.4186	109.6792	68.3293
445.0	19.5064	221.7679	109.0454	68.3066
455.0	18.5076	221.1408	108.4215	68.2745
465.0	17.5031	220.5414	107.8287	68.2712
475.0	16.5348	219.9562	107.2123	68.2531
485.0	15.6227	219.3774	106.5964	68.2319
495.0	14.7729	218.8026	105.9645	68.2249
505.0	13.9865	218.2297	105.382	68.1818
515.0	13.2683	217.6576	104.7573	68.1386
525.0	12.6162	217.0859	104.1976	68.095
535.0	12.0188	216.514	103.6427	68.0594
545.0	11.4678	215.9416	103.0722	68.0346
552.5	10.5827	214.8401	102.0021	68.0093
557.5	9.361	213.2455	100.393	68.3467
562.5	8.1358	211.6863	98.9062	68.4692
567.5	6.8944	210.1651	97.5417	68.3702
572.5	5.744	208.6841	96.3328	68.1967
577.5	4.6941	207.2462	94.8919	68.1705
582.5	3.7314	205.8537	93.5044	68.2115
587.5	2.8084	204.5095	92.1647	68.212
592.5	2.0033	203.2163	90.8465	68.2573
597.5	0.4579	201.9765	89.5812	68.2749
602.5	0.0	200.7927	88.3465	68.3211
607.5	0.0	199.6672	87.1664	68.3747
612.5	0.0	198.6021	86.0739	68.4004
617.5	0.0	197.5985	85.0658	68.401
622.5	0.0	196.6568	84.1177	68.4116

Appendix 2C: Range graph values for case 3 (Line 6)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
627.5	0.0	195.7762	83.2314	68.4365
632.5	0.0	194.9562	82.4253	68.47
637.5	0.0	194.1955	81.7269	68.5225
642.5	0.0	193.4917	81.1423	68.4949
647.5	0.0	192.844	80.6525	68.5035
652.5	0.0	192.2493	80.1748	68.6215
657.5	0.0	191.7043	80.1853	68.205
662.5	0.0	191.2078	79.1396	68.922
667.5	0.0	190.758	78.5564	69.3776
672.5	0.0	190.3495	77.7084	69.7872
677.5	0.0	189.9793	76.6119	70.177
682.5	0.0	189.6496	75.8201	69.9408
687.5	0.0	189.3551	75.5299	69.8491
692.5	0.0	189.1508	75.4217	69.6229
697.5	0.0	188.9789	75.4764	69.2823
702.5	0.0	188.8415	75.5279	68.8694
707.5	0.0	188.7387	75.5733	68.3884
712.5	0.0	188.6606	75.6357	67.8687
717.5	0.0	188.6102	75.6815	67.3008
722.5	0.0402	188.5942	75.7533	66.6991
727.5	0.2721	188.0251	75.8017	66.0756
732.5	0.7158	187.0234	75.7455	65.4724
737.5	1.3538	185.9362	75.8843	64.7921
742.5	2.1076	184.9867	76.0665	64.1082
747.5	2.9078	184.0871	76.3878	63.3747
752.5	3.7582	183.1561	76.7769	62.6062
757.5	4.6057	187.8786	76.74	62.0642
762.5	5.4789	194.038	76.9061	61.4106
767.5	6.1482	198.29	77.0215	60.7808
772.5	6.5695	197.7151	76.9551	60.1841
777.5	6.4181	192.6361	76.8567	59.4964
782.5	2.4309	187.3002	76.41	59.0784
787.5	0.0	186.3675	76.0349	58.8155
792.5	0.0	189.9599	75.8116	58.6909
797.5	0.0	194.8576	75.7525	58.6724
800.0	0.0346	194.8933	75.7854	58.6698

Appendix 2C: Range graph values for case 3 (Line 7)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
0.0	55.0867	197.2157	119.3974	45.4525
2.5	54.0824	195.8518	118.2329	45.4119
7.5	54.2451	228.5895	130.3336	57.1237
12.5	52.1445	226.5514	128.2039	57.1578
17.5	50.2258	224.5154	126.0689	57.1526
22.5	48.4562	222.5082	123.9416	57.1577
27.5	46.8118	220.5042	121.821	57.109
32.5	45.2763	218.4913	119.7247	57.0235
37.5	43.5718	216.4754	117.6657	56.9114
42.5	41.7578	214.4846	115.6443	56.8163
47.5	39.9803	212.4901	113.5975	56.769
55.0	38.7775	211.1344	112.2177	56.7595
65.0	38.1573	210.4124	111.3736	56.7694
75.0	37.5743	209.6809	110.5699	56.774
85.0	37.0215	208.9413	109.7734	56.759
95.0	36.4869	208.1953	108.9949	56.7277
105.0	35.9542	207.4444	108.2264	56.6934
115.0	35.4114	206.6905	107.4646	56.675
125.0	34.8743	205.9366	106.6737	56.6219
135.0	34.363	205.189	105.9349	56.6188
145.0	33.8873	204.4638	105.2385	56.6152
155.0	33.4458	203.753	104.5635	56.6125
165.0	32.762	203.0458	103.8907	56.6088
175.0	32.0772	202.3383	103.2523	56.6155
185.0	31.4223	201.6285	102.625	56.6381
195.0	30.7982	200.9153	101.9279	56.6409
205.0	30.2045	200.1984	101.1867	56.6354
215.0	29.64	199.4776	100.4405	56.6284
225.0	29.1036	198.753	99.6981	56.6186
235.0	28.592	198.0252	98.9755	56.6199
245.0	28.0988	197.3254	98.2627	56.607
255.0	27.6089	196.6782	97.5452	56.5727
265.0	27.097	196.0297	96.8341	56.5327
275.0	26.5849	195.3786	96.1352	56.4929
285.0	26.0974	194.7241	95.4342	56.4647
295.0	25.511	194.0651	94.725	56.4423
305.0	24.9249	193.4013	94.0038	56.4291
315.0	24.4355	192.7318	93.2773	56.4397

Appendix 2C: Range graph values for case 3 (Line 7)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
325.0	24.0053	192.0562	92.5558	56.4217
335.0	23.544	191.3746	91.8756	56.3728
345.0	23.0297	190.6874	91.1854	56.3482
355.0	22.5502	189.9953	90.5203	56.3033
365.0	22.1666	189.2999	89.8868	56.2815
375.0	21.8509	188.6036	89.2644	56.2617
385.0	21.4019	187.9094	88.603	56.2378
395.0	20.824	187.2219	87.933	56.208
405.0	20.0986	186.5471	87.2749	56.1993
415.0	19.3436	185.8896	86.6349	56.188
425.0	18.4373	185.2455	86.0098	56.1837
435.0	17.5552	184.6084	85.3978	56.1909
445.0	16.7246	183.9744	84.7421	56.1642
455.0	15.9418	183.3416	84.1106	56.161
465.0	15.2091	182.7088	83.475	56.1505
475.0	14.5397	182.0755	82.8725	56.1246
485.0	13.9383	181.4415	82.3117	56.0897
495.0	13.4066	180.8076	81.7371	56.0373
505.0	12.9383	180.1749	81.1317	56.0074
515.0	12.521	179.5453	80.4782	55.9909
525.0	12.1312	178.922	79.8984	56.0046
535.0	11.7206	178.3097	79.2857	55.9913
545.0	11.3081	177.7186	78.7154	55.9872
552.5	10.6472	176.6545	77.6227	56.1152
557.5	0.0	175.1743	75.8847	57.1335
562.5	0.0	173.7509	74.6845	57.3465
567.5	0.0	172.3823	73.4402	57.3347
572.5	0.0	171.0712	72.1107	57.2209
577.5	0.0	169.8194	70.8438	57.0555
582.5	0.0	168.6294	69.8427	56.8436
587.5	0.0	167.5032	68.8492	56.7383
592.5	0.0	166.4422	67.5976	56.8738
597.5	0.0	165.4472	66.6078	56.9052
602.5	0.0	164.5182	65.6817	56.9411
607.5	0.0	163.6546	64.8036	56.9853
612.5	0.0	162.8544	64.0522	57.0305
617.5	0.0	162.1152	63.4007	57.1692
622.5	0.0	161.4335	63.1185	57.3588
627.5	0.0	160.8134	62.9496	57.6388
632.5	0.0	160.3022	61.735	58.2691
637.5	0.0	159.8421	60.8662	58.7667
642.5	0.0	159.432	59.4355	59.0215
647.5	0.0	163.8013	58.5459	58.9987
652.5	0.0	158.7292	57.3133	58.5658
657.5	0.0	172.9255	57.1787	58.7139

Appendix 2C: Range graph values for case 3 (Line 7)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
662.5	0.0	158.1706	56.9923	58.1368
667.5	0.0	157.9291	57.002	57.6209
672.5	0.0	157.7211	57.128	57.0638
677.5	0.0	157.5421	57.3049	56.4576
682.5	0.0	157.3826	57.537	55.7929
687.5	0.0515	157.2518	57.8035	55.0827
692.5	0.5139	156.5059	58.0839	54.3426
697.5	1.2848	155.4703	58.4141	53.7404
702.5	2.1389	157.9512	58.8673	53.3457
707.5	2.9872	170.6643	59.3228	52.9753
712.5	3.8253	177.0797	59.7395	52.553
717.5	4.6455	177.5331	60.2011	52.0402
722.5	5.4526	173.9622	60.5789	51.5272
727.5	5.2003	169.5937	60.9649	51.027
732.5	4.5695	175.5448	61.3743	50.604
737.5	4.2162	180.956	61.871	50.3006
742.5	2.658	186.2098	62.3564	49.965
747.5	0.7977	192.6796	62.79	49.6155
752.5	0.0	197.9529	63.2411	49.271
757.5	0.0	202.8437	63.7276	48.9043
762.5	0.0	207.5733	64.2027	48.5397
767.5	0.0	212.1476	64.6562	48.165
772.5	0.0	215.0319	65.1484	47.7594
777.5	0.0	216.5607	65.6062	47.334
782.5	0.0	219.1892	66.0259	46.9588
787.5	0.0	223.8284	66.4105	46.7277
792.5	0.0	228.933	66.8126	46.6268
797.5	0.0	235.0597	67.3714	46.6688
800.0	0.768	235.8222	68.0924	46.6266

Appendix 2C: Range graph values for case 3 (Line 8)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
0.0	45.9087	297.0086	154.9202	82.841
2.5	44.9463	296.0302	154.2377	83.0153
7.5	53.7292	299.7582	167.4018	83.9546
12.5	52.048	297.6693	165.2765	83.96
17.5	49.9229	295.7885	163.1477	83.9307
22.5	47.874	293.891	161.0462	83.8492
27.5	45.9769	291.9738	158.988	83.7372
32.5	44.2313	290.0356	156.9803	83.5809
37.5	42.6118	288.0768	155.0225	83.3927
42.5	41.0546	286.0985	153.1278	83.2012
47.5	39.408	284.1041	151.2535	83.0516
55.0	38.1617	282.7433	149.9462	83.0062
65.0	37.5029	282.0116	149.2006	83.0057
75.0	36.8761	281.2677	148.4243	83.0042
85.0	36.2757	280.5154	147.6817	82.9799
95.0	35.6925	279.7591	146.9935	82.8975
105.0	35.1152	279.0036	146.2967	82.8433
115.0	34.5433	278.2539	145.5865	82.8337
125.0	33.9817	277.5167	144.8884	82.8043
135.0	33.3481	276.7989	144.2161	82.789
145.0	32.7461	276.098	143.5407	82.7611
155.0	32.2367	275.4076	142.8713	82.717
165.0	31.8023	274.7234	142.1591	82.6585
175.0	31.4464	274.042	141.4691	82.6064
185.0	31.1493	273.3601	140.7741	82.5493
195.0	30.8719	272.6751	140.1191	82.4945
205.0	30.6071	271.9857	139.4917	82.4436
215.0	30.3686	271.2921	138.9277	82.4635
225.0	30.109	270.5942	138.2907	82.4565
235.0	29.8104	269.8931	137.6147	82.4375
245.0	29.4117	269.1897	136.8855	82.4211
255.0	28.8505	268.4858	136.1361	82.3895
265.0	28.217	267.7852	135.3921	82.356
275.0	27.5466	267.096	134.664	82.3351
285.0	26.9053	266.4312	133.951	82.2899
295.0	26.3226	265.7976	133.2756	82.259
305.0	25.8117	265.1859	132.6329	82.2414
315.0	25.3701	264.5814	131.99	82.2457

Appendix 2C: Range graph values for case 3 (Line 8)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
325.0	24.9977	263.9754	131.3707	82.2473
335.0	24.6734	263.3634	130.7604	82.2392
345.0	24.3589	262.7429	130.1569	82.23
355.0	24.0086	262.1123	129.567	82.2123
365.0	23.5108	261.4708	128.9229	82.1949
375.0	22.9014	260.8183	128.2688	82.1877
385.0	22.3286	260.1548	127.6231	82.1713
395.0	21.7829	259.4818	126.9529	82.1525
405.0	21.1515	258.8003	126.3325	82.1095
415.0	20.4486	258.1129	125.7399	82.0722
425.0	19.6475	257.424	125.1449	82.043
435.0	18.9093	256.7452	124.5766	82.0336
445.0	18.2561	256.1468	124.0086	82.0293
455.0	17.6856	255.6343	123.4385	82.0349
465.0	17.1254	255.132	122.8038	82.0446
475.0	16.5238	254.6301	122.165	82.0571
485.0	15.9806	254.1246	121.6987	82.0185
495.0	15.4636	253.6135	121.0785	82.01
505.0	14.905	253.095	120.4742	81.9993
515.0	14.231	252.5677	119.8588	81.9832
525.0	13.4748	252.0305	119.2939	81.9702
535.0	12.7297	251.4829	118.7026	81.9455
545.0	12.0392	250.9245	118.1517	81.9664
552.5	10.959	249.8283	117.147	81.8739
557.5	9.4788	248.2294	115.5539	82.1866
562.5	8.1646	246.6551	114.1354	82.3282
567.5	7.0265	245.1084	112.8495	82.2899
572.5	6.0195	243.5919	111.4551	82.2555
577.5	5.1276	242.1092	110.0143	82.1788
582.5	3.5925	240.6649	108.5435	82.1499
587.5	3.2556	239.2664	107.1578	82.0867
592.5	2.9962	237.9406	105.8072	82.097
597.5	2.1736	236.7457	104.5137	82.0686
602.5	1.5488	235.6152	103.3062	82.0407
607.5	1.0633	234.5381	102.1463	82.0272
612.5	0.4423	233.5126	101.0383	82.0237
617.5	0.0	232.5385	100.0013	82.017

Appendix 2C: Range graph values for case 3 (Line 8)

Arc Length (m)	Minimum	Maximum	Mean	Std. Dev.
622.5	0.0	231.6156	99.0586	82.0206
627.5	0.0	230.7442	98.2545	82.0226
632.5	0.0	229.9238	97.468	82.1007
637.5	0.0	229.1537	96.6651	82.1844
642.5	0.0	228.4339	95.914	82.2789
647.5	0.0	227.7633	95.3078	82.4527
652.5	0.0	227.1417	94.8359	82.7099
657.5	0.0	226.5686	94.3932	82.8989
662.5	0.0	226.0425	93.8621	83.0419
667.5	0.0	225.5614	93.6331	83.2533
672.5	0.0	225.1241	93.6821	82.9278
677.5	0.0	224.7301	93.22	83.0881
682.5	0.0	224.3758	92.3478	83.6478
687.5	0.0	224.0612	91.0547	84.6809
692.5	0.0	224.829	89.9857	85.191
697.5	0.0	228.0022	88.6849	85.5548
702.5	0.0	230.6009	88.4707	85.6135
707.5	0.0	233.2065	87.7422	85.1183
712.5	0.0	236.1741	87.6801	84.992
717.5	0.0	239.2834	87.4827	84.8795
722.5	0.0	242.5589	87.5195	84.5711
727.5	0.0	245.575	87.7308	84.1466
732.5	0.0	248.6458	87.9857	83.5478
737.5	0.0686	252.5272	88.0833	83.0324
742.5	0.3191	256.5412	88.0451	82.6319
747.5	0.0	259.9671	88.2979	82.131
752.5	0.0	260.4906	88.413	81.4608
757.5	0.0	258.5301	88.5509	80.7311
762.5	0.0	256.8878	88.8858	80.0109
767.5	0.0	254.5355	89.4108	79.2165
772.5	0.0	253.7072	89.8552	78.473
777.5	0.0	255.4389	90.2161	77.9331
782.5	0.0	256.9547	90.6279	77.4206
787.5	0.0	257.5681	91.1706	77.1388
792.5	0.0	257.6425	91.6227	77.026
797.5	0.0	258.2662	91.6337	77.0734
800.0	0.0342	258.3019	91.6662	77.0703