Norwegian University of Science and Technology
Department of Marine Technology

MASTER THESIS

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Abstract

Understanding the behavior of a mooring line that is connected to a Suezmax vessel is a crucial requirement for our industry. Thus, we should model and analyze such a mooring line under a variety of environmental conditions. The output of modeling and analysis are useful to determine if the given mooring line is suitable for that environment or not.

In the first part of this project a brief description about floating production platforms and mooring systems has been given and different material used for mooring systems has been discussed. All loads acts on mooring systems have been described and design methods used for mooring system analyses with relevant equation have been summarized. Brief descriptions about standards and guidelines used for mooring analysis have been given.

Since we will use RIFLEX software for mooring line analysis, a brief introduction about the concept of the software will be provided. A single mooring line is studied that consists of two material compositions and is connected to Suezmax vessel. In the last part of this thesis, static and dynamic analysis in two regular wave cases will be performed for given mooring lines. We will do the analyses under three tensions 15%, 30% and 45% MBL (Minimum Breaking Load) in two vessel conditions (i.e. ballasted and loaded). The main focus is on effective tension and line displacement determination, that a given mooring line experiences. The results have been discussed.

Keyword:

- Floating production units
- Mooring systems
- Static and dynamic analysis

Advisor:

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MASTER THESIS

Master thesis, Spring 2011
for
Stud. Techn. Leila Keshavarz

Analysis of Mooring System for a Floating Production System

Analyse av Forankrings-system for et Flytende Produksjons-system

The dynamic effect on a mooring line depends on the seastate, vessel size, mooring line composition, load level and water depth. The objective of the proposed thesis work is to establish a guideline of the dynamic mooring line load relative to the quasi-dynamic load (vessel motion included but without line dynamics such as drag and inertia effects). Basis for the study will be a typical Suezmax vessel in ballast and/or loaded condition, with 15 deg heading relative head waves. Software to be used is Riflex based on regular waves.

The following subjects are to be examined in this thesis:

1. The candidate shall give a brief description of different types of Floating Production Systems. The types of mooring components which are relevant for these Production Systems are also to be summarized. The types of materials applied, the loads acting on the mooring system shall be described, and methods for computation of load-effects shall be elaborated.

2. A specific floating production unit with corresponding mooring system is to be selected for response analysis. The data describing the system are to be provided by APL. The values of relevant parameters which are not given (e.g. added mass and drag force coefficients) are to be selected in accordance with DNV-OS-E301 (and DNV-RP-C205).

3. Having made a numerical model of the system, a number of parameter variations are to be performed based on discussion with the supervisor and the contact person in APL. A range of different regular waves and water depths are be considered.

4. Comparison is to be made between the response levels obtained from static versus dynamic analyses. Implications with respect to possible simplified design analyses based on a static approach are to be discussed.

The work-scope may prove to be larger than initially anticipated. Subject to approval from the supervisor, topics may be deleted from the list above or reduced in extent.

In the thesis the candidate shall present his personal contribution to the resolution of problems within the scope of the thesis work. Theories and conclusions should be based on mathematical derivations and/or logic reasoning identifying the various steps in the deduction. The candidate should utilise the existing possibilities for obtaining relevant literature.

The thesis should be organised in a rational manner to give a clear exposition of results, assessments, and conclusions. The text should be brief and to the point, with a clear language. Telegraphic language should be avoided.

The thesis shall contain the following elements: A text defining the scope, preface, list of contents, summary, main body of thesis, conclusions with recommendations for further work, list of symbols and acronyms, references and (optional) appendices. All figures, tables and equations shall be numerated.

The supervisor may require that the candidate, at an early stage of the work, presents a written plan for the completion of the work. The plan should include a budget for the use of computer and laboratory resources which will be charged to the department. Overruns shall be reported to the supervisor.

The original contribution of the candidate and material taken from other sources shall be clearly defined. Work from other sources shall be properly referenced using an acknowledged referencing system.

The thesis shall be submitted in 3 copies:

- Signed by the candidate
- The text defining the scope included
- In bound volume(s)
- Drawings and/or computer prints which cannot be bound should be organised in a separate folder.

Supervisor: Professor Bernt J. Leira Contact person at APL: Geir Olav Hovde

Start: January 17th, 2011 Deadline: June 14th, 2011

Trondheim, 17 January 2011

Bernt J. Leira

Preface

This master thesis is written at spring 2011by Leila Keshavarz at the ‘‘ Department of Marine Technology-Marine Structures‘‘ at MTS, NTNU. This thesis is written in close cooperation with APL Company.

I would like to thank my supervisor, professor Bernt J.Leira for the support throught the semester. Further on I would like to thank Geir Olav Hovde for giving me the good information and practical understanding of RIFLEX software.

1. Introduction

Offshore structures are mainly used in oil and gas industry and widely used and installed worldwide. Offshore structures are divided to fixed and floating structures. While fixed structures were expensive and more difficult to install when water depths increased floating structures were developed which cheaper and easy to secure. Mooring and station keeping are used for controlling movement of floating structures against the environmental loads. Mooring system is consist of chains, cables, ropes and anchors which connected between seafloor and structure. Station keeping is used to keep the structure in a specified distance from a desired location. This term may be attained by using adjustable mooring lines or dynamic positioning system using thrusters or a combination of two.

The types of deepwater production are illustrated in figure 1.1.

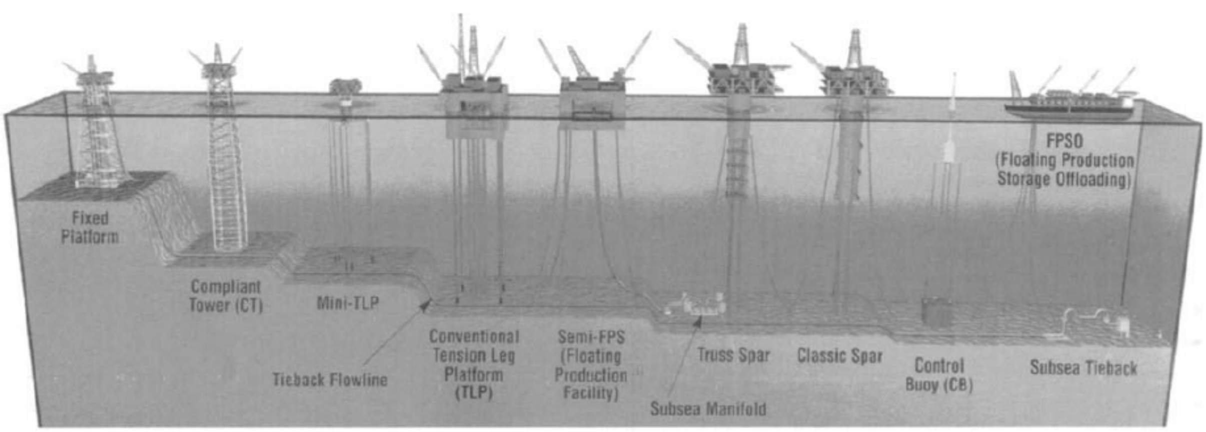

Figure 1.1 Deepwater system types (offshore magazine, 2002) (1)

For design and analysis of mooring systems, in addition to environmental forces acting on the system, the influence of floating structure which responds dynamically to environmental forces including translation and rotation of the floater should also be considered.

Steel linked chain and wire rope have usually been used for mooring system but with increasing water depth, the weight of mooring lines becomes a limiting factor. A good alternative for deep water mooring is synthetic fiber rope.

Several design methods (static, Quasi-Static and Dynamic) applied for analysis of mooring system. Static analysis often carried out at the very initial stages of the mooring system design. Quasi-static analysis is more complex and considers non-linear effect and dynamic analysis include all loads from the mooring system in addition to restoring forces, specifically the hydrodynamic damping effects introduced by relative motion between the line and fluid.

The purpose of this thesis is to give a brief description of mooring systems which are relevant for Floating Production Systems and material types used for these mooring lines. Also, the loads acting on mooring systems and methods for computation of load effects will be summarized.

Static and dynamic response analysis for a mooring line connected to Suezmax vessel will be done by RIFLEX computer program for regular waves.

2. Floating production system

Various floating structures have different degrees of freedom. Structures like semi-submersibles and spar which are neutrally Buoyant have six degrees of freedom (heave, surge, sway, pitch, roll and yaw) and they are dynamically unrestrained. Other structures such as the Tension Leg Platforms (TLPs) are positively buoyant and tethered to the seabed so they are restrained in heave direction. All of these structures are rigid and their compliancy is achieved with the mooring system.

2.1. Production Units (FPSO and FPS)

A floating production, storage and offloading (FPSO) unit is a floating vessel used by the offshore industry for the processing and storage of oil and gas. Regarding to suitability of FPSO and FPS in deep water the use of them increased all around the world (see figure 2.1).

The FPSO is ship-shaped structures which will restrain with different mooring systems.

Spread mooring system is used in shallow water and in mild environment while internal and external turrets are used for deep water and harsh environments.

In deepwater locations which seabed pipeline will be expensive and in remote areas where pipe-laying distance from well to onshore is long, using FPSOs are strongly recommended.

FPSOs can be used economically for small oil fields with short life time which installing the fixed platform is expensive. Some FPSOs in emergency time can release their mooring line and move away to safe position and reconnect them later.(1)

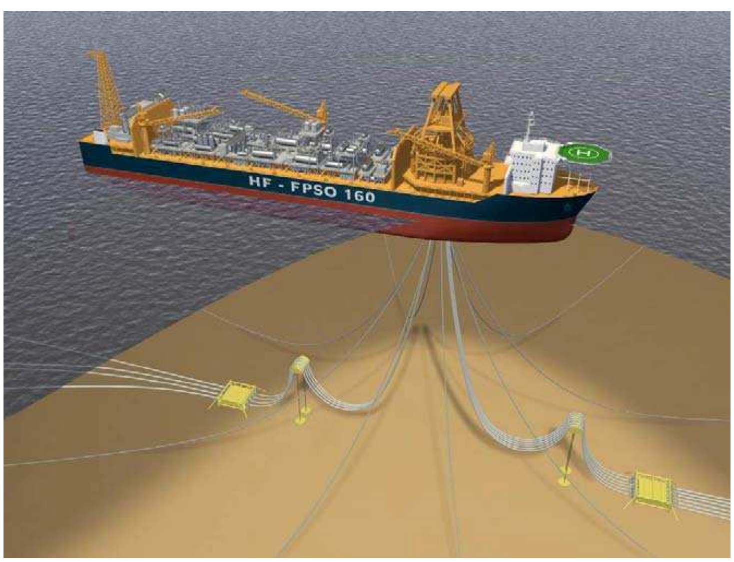

Figure 2.1 Ship-shaped FPSO

2.2. Semi-Submersible Platform

A semi-submersible has good stability and sea-keeping characteristics. For offshore drilling rigs, oil production platforms and heavy lift cranes, semi-submersible vessel design is commonly used (see figure 2.2).

Semi-submersible is multi-legged floating structure with a large deck. These legs are interconnected at the bottom to the pontoons which are horizontal buoyant parts. Pontoons of some earlier semi-submersibles had a bow and stern shape like ships. This shape was more convenient for moving or towing a semi-submersible by tugs from one place to another. Also, they had diagonal cross bracing to resist loads induced by waves.

The new semi-submersibles typically are square with four columns connected to the box or cylinder shaped pontoons. For better station keeping of box shaped pontoons the sharp edges are eliminated. Also, diagonal bracing is eliminated for more simplicity in construction.

Semi-submersible platforms can be used in different places by moving from one place to another and by ballasting or de-ballasting of buoyancy tanks they can use in different water depths. This capability is used for heavy lift vessels to submerge the majority of their structure and locate bellow another floating vessel and pick up it as a cargo by de-ballasting their buoyancy tanks.

During drilling, production and operations mooring system consist of chain, wire rope or dynamic positioning system is generally used to keep the structure in a desired position.

Figure 2.2 Semi-submersible platform

2.3. Spar

The SPAR is a deepwater drilling and production platform. Spars have been designed in three configurations: the conventional cylindrical hull, truss and cell spar (see figure 2.3).

The conventional spar comprises a vessel with a vertical circular cross-section sits in the water and supported by buoyancy chambers at the top and stabilized by a midsection structure hanging from the hard tanks. If necessary, solid ballast may be placed in compartment at the keel to increase the stability. Truss spar has truss elements in midsection which is connecting the upper buoyant hull, called a hard tank, to the bottom soft tank containing permanent ballast. The cell spar is built from multiple vertical cylinders.

When the wellhead equipment is located on the platform instead of on the seabed dry tree technology is used for reducing the cost and maintenance work.

The Spar build for small and medium sized rigs may be more economical and has more stability since it has a large counterweight at the bottom and does not depend on the mooring to hold it upright. Spar can move horizontally over the oil filed by using of chain-jacks attached to the risers.

The vessel is anchored to seafloor by taut catenary mooring lines which attached to near its center of pitch for low dynamic loading, provides good lateral station keeping. Since the interaction between hull and mooring system is good the spar uses taut catenary mooring system of chain and wire connected in piled anchors at seabed. This system is more convenient and economical.

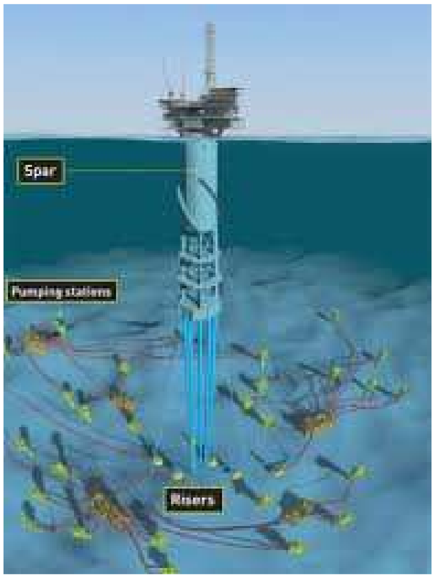

Figure 2.3 Spars

2.4. Tension Leg Platform

A Tension Leg Platform (TLP) is a vertically moored platform (see figure 2.4). The high buoyant floating platform is permanently moored by taut mooring lines called tendons, or tethers. High axial stiffness and low elasticity of the tethers is important for design. The structure is vertically restrained prohibiting vertical (heave) and rotational (pitch and roll) motions but in the horizontal direction lateral motions (surge and sway) are permitted.

TLP designers are trying to keep the natural periods in heave and pitch below the range of significant wave energy. To achieve this pipe wall thickness of the tendons are increased to control heave period and for reducing pitch period, distance between tendons are increased to attain more stiffness. However, it makes large deck area with large spans which supporting of it will be more expensive but allows the platform to have the production wellheads on deck, connected directly by rigid risers to the subsea wells, instead of on the seafloor. Also, this permits a simpler well completion and gives better control over the production from the oil or gas reservoir, and easier access for downhole intervention operations. (2)

Figure 2.4 Tension leg platform

3. Mooring systems

3.1. Overview

In the design and operation of floating production systems station-keeping is one of the most important factors from a safety and cost point of view.

A number of lines and anchors located in various ways can show a mooring system. Spread catenary mooring system is used for monohull and semi submersibles. For monohulls large environmental loads will act on the mooring system due to excessive offset. Single point mooring (SPM) were developed to overcome this disadvantage, the mooring lines connected to the vessel at a single connection point of the vessel on its longitudinal centre line. Although SPM is a good solution for spread mooring but it involves many complex components and is subjected to severe limitations. Turret mooring systems which are more economical and reliable than SPM have been developed recently for monohulls.

Nowadays turret mooring is mostly used and for reducing loads on mooring system disconnectable mooring system have been developed.

In past mooring for floating production platforms mostly were passive systems. Steel-linked chain and wire rope have usually been used for mooring floating platforms in deep water. For harsh weather mooring systems with combination of dynamic positioning systems is used. These help to reduce loads in the mooring lines by turning the vessel, or reducing offsets.

In this section the fundamentals of mooring systems are briefly discussed.

3.2. Catenary line

A mooring system consists of number of lines which its upper end is attached to the floating structure at different points and lower end anchored at the seabed (see figure 3.1). Mooring lines arranged to keep the structure in desired position and provide essentially resistance against movement of the structure.

Mooring lines are built up of wire rope, chain or combination of them. The ropes material is steel, natural fiber and synthetic fibers. Combinations of different material in catenary line are used to get grater stiffness and lighter anchor line. Light segment is placed near to water surface and heavy segment close to seabed. The tension force in the cable due to its weight or elastic properties depend on laying system. Pre-tension in a cable will apply by winches.

Horizontal force applied on catenary line at the seabed and sea surface will keep the structure in desired position and will get their restoring force from the weight of line.

The catenary mooring should not be used in deep water because the footprint of mooring system will increase and large seabed area will occupy. The problem of increasing mooring weight can be solved by using synthetic fiber ropes which are lighter, flexible and can absorb imposed dynamic motion through extension without causing more dynamic tension.

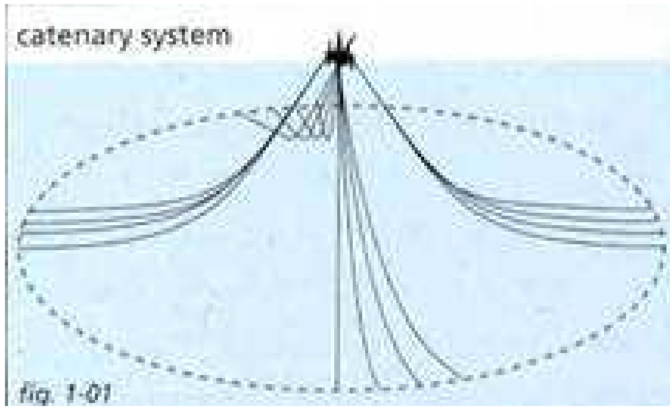

Figure 3.1 catenary mooring

3.3. Taut mooring

For deep water depths, in the design of a floater the weight of the mooring line becomes a limiting factor. To overcome this problem, synthetic ropes which are lighter and a taut mooring system can be applied (see figure 3.2). When the taut mooring is placed at the seabed at an angle, the anchor point will resist both horizontal and vertical forces. The elasticity of the mooring lines is caused the restoring forces then line should have adequate elasticity to absorb the vessel wave motions without overloading. The footprint of the taut mooring is smaller than the footprint of the catenary mooring and it has a much more liner stiffness than the stiffening catenary systems. Also, taut mooring has better load sharing between adjacent lines which improved overall efficiency of the system and shorter line than catenary system at similar depth. A taut mooring will usually have an angle of between 30 and 45 degrees to horizontal at the vessel and display linear load-excursion characteristics. Laying taut mooring on crowded seafloor reduce the risk of clashing between mooring lines and pipelines or subsea equipments.

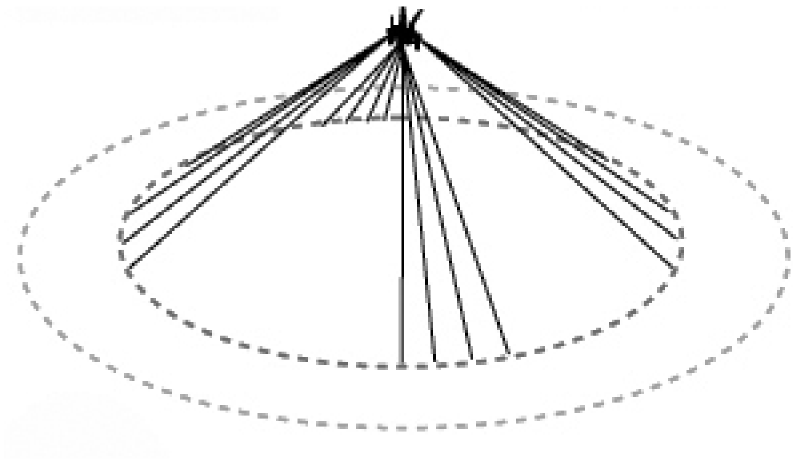

Figure 3.2 Taut mooring

3.4. Tension leg mooring

This mooring system is used for buoyant structures and consists of a set of tension legs or tendons attached to the platform and connected to a template or foundation on the seafloor (see figure 3.3). The vertical equilibrium of the platform is achieved by existence of tension legs, tethers or tendons because the buoyancy of the hull exceeds the weight of the platform.

Tendons should always keep in tension for all weather and loading conditions to compensate buoyancy over the platform weight. Tendons are made of tubular pipes, cables and wire ropes of certain strength. These tendons allow the platform to move in a horizontal plane (surge, sway and yaw) but restrict its motions in a vertical plane (heave, pitch, and roll).

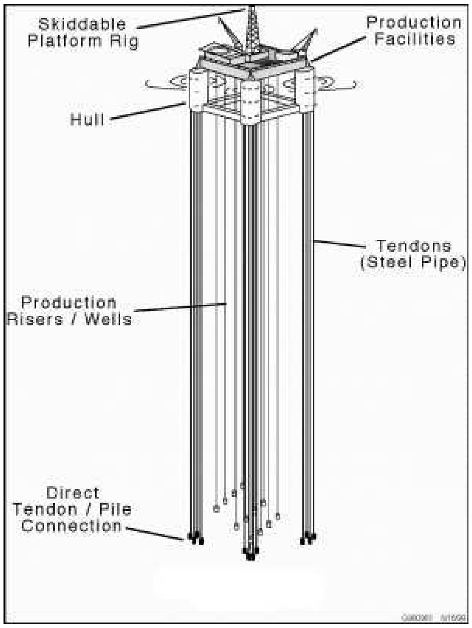

Figure 3.3 Tension leg mooring

3.5. Dynamic positioning system

Nowadays DP systems can be found on many types of vessels: drilling vessels, heavy lift vessels, installation vessel, cable and pipelaying vessels and FPSOs. Vessels with DP system can resist environmental loads without the need for anchors and will remind in desired position by thrusters and at a fixed heading. Instead of mooring lines, Dynamic Positioning (DP) and Dynamic Tracking (DT) are used to keep a vessel at a specific position (DP) or track (DT) using thrusters. The vessel DP system can determine its position error by measuring its position, and heading, and comparing it to the required position.

Thruster action which need to keep the vessel as close as possible to required position ensure by control system. For keeping the vessel in position, dynamic positioning system is used which can control the magnitude and the direction of thrust by getting feedback from changing in position.

Dynamic positioning system consists of two circuits: low voltage and high voltage circuits.

For the control systems low voltage circuit is used and for the power supply of the thrusters high voltage circuit is used.

The thruster mechanism for keeping the vessel in specified position is that it should create thrust in longitudinal and transverse direction and torque around a vertical axis located in center of gravity of the ship. Several types of sensors can be used for keeping the vessel in position by sending feedback to the DP system and drive the thrusters, controller and propelling machinery such as motion reference units, wind sensors and draught sensors.

3.6. Anchors

Between different types of anchors which are available, five types are identified: the dead weight, drag embedment anchor, pile, suction anchor and the vertical load anchor (VLA).

3.6.1. Deadweight anchor

This is a heavy weight anchor which is laid solely on seabed. It consists of a large block of concrete or stone at the end of the chain. Regardless of the type of seabed anchor holding capacity is defined by its underwater weight and buoyancy. Where mushroom anchors are inappropriate in rock, gravel or coarse sand seabed the deadweight anchors can be used.

Using deadweight anchor instead of mushroom anchor has an advantage, when it does become dragged then it will present its original holding force. The disadvantage of using deadweight anchors over a mushroom anchor is that it needs to be about ten times the weight of the same mushroom anchor. (4)

3.6.2. Drag Embedment Anchor

A kind of anchors which has been designed to penetrate into the seabed is the drag embedment anchor. The resistance of the soil in front of the anchor will generate the holding capacity. The anchor is suitably designed to resist horizontal forces but cannot carry vertical forces.

3.6.3. Pile Anchor

A hollow steel pipe which is hammered or vibrated into the seabed is pile anchor. Friction of the soil along the pile and lateral soil resistance will generate the holding capacity of the pile. it can thus withstand both vertical and horizontal forces.

3.6.4. Suction anchor

A steel pipe with closed top is a suction anchor. A pump which is installed on top of the pipe is capable to control the pressure inside the pile. The pile is pressed into the seabed by the hydrostatic head of water on top of the pile. the holding capacity of the suction anchor is as same as plie anchor and can generated by friction of the soil along the anchor and lateral soil resistance and it can also thus resist both vertical and horizontal forces. (4)

3.6.5. Vertical load anchor

Installation method for the vertical load anchor is same as other anchors but penetration is much deeper. Vertical loading anchor can resist both horizontal and vertical loads. High installation cost is the major disadvantage for this anchor type because it needs specific installation procedures and special offshore equipment and highly trained staff.

4. Risers

Risers are used for transport of hydrocarbons from a subsea well to or via a production / storage unit positioned at the sea surface. Variety of risers depends on field parameters, such as environmental conditions, platform concept, production rates, well pressure/temperature, water depth, flow assurance, installation issues. Also riser systems similar to the production riser may be used for other applications like injection of gas or produced water into the well or for export of hydrocarbons. The following categories of risers are typically used for exploitation of hydrocarbons:

- Production riser
- Injection riser
- Gas lift riser
- Service riser
- Export / import riser
- Completion / Workover riser
- Marine Drilling riser system
- Subsea Control Umbilical
- Integrated Production Umbilical.

These categories can change according to some parameters like typical dimensions, cross-sectional composition, type of operation, functional requirements and design load conditions.

For mentioned applications some of the following characteristic riser designs can be distinguished:

- Top tensioned riser (TTR); a riser supported by combination of top tension and boundary conditions that permits the riser or floater to move in vertical direction, for example using heave compensation system. The ideal behavior is that the top tension has a constant target value without effect of floater motion. The important design parameter which has an effect on the mechanical behavior and the application range is the capacity of relative riser/floater motion in vertical direction in addition to applied top tension. TTR's are also can be used for floaters with small heave motion.

- Compliant riser; are mostly used as production, export/import and injection risers. The concept design of compliant riser is the absorption of floater motions by change of geometry, without use of heave compensation systems. For normal water depths required flexibility is obtained by using unbounded flexible pipes. Steep S, Lazy S, Steep Wave, Lazy Wave, Pliant Wave or Free Hanging (catenary) is the conventional compliant riser configurations. Compliant Vertical Access Riser (CVAR) is a non- conventional riser. In deep water metallic pipes are also can be used as compliant riser. The wave zone, hog-bend, sag-bend, touchdown area at seafloor and at the terminations to rigid structures, e.g. I- or J-tubes are the critical locations on the compliant riser.

- Hybrid riser; are mainly used as production, export/import and injection risers. For design of the hybrid risers, the combination of the tensioned and the compliant riser are efficiently used. A typical model is a compliant riser from the buoy to the FPS and a vertical/free hanging riser from a submerged buoy to seabed. A riser tower is a bunch of compliant vertical risers connected from seabed to the FPS. Various methods such as truss support structure, distributed buoyancy on the risers and buoyancy tanks can be use for assembly of vertical risers. For non-stationary and dynamic riser various services are used.

The following options for dynamic riser systems are illustrated:

- Metallic risers (i.e. steel, titanium)
- Composite risers
- Flexible pipes
- Umbilicals (i.e. individual or piggy-back)
- Loading hoses.

Flexible risers (flexible pipes) are from the bonded or unbonded type. Both types consist of flexible pipe segments with end fittings attached to both ends. Both types of flexible risers are multilayer and for overall protection riser layers are started with inner layer and completed by protective layer. In bonded types all layers are tied together by use of glues or heat or pressure to fuse the layers into a single construction while in unbonded pipes there is no connection between various layers but the most favorable flexible riser type is unbonded pipes.

The umbilicals may be used for optical fiber data communications, gas lift, electrical services, hydraulic or chemical functions or a combination of these. A bunch of helical or sinusoidal wound small diameter conductors is umbilical and can be used for power and control systems.

5. Material

5.1. Chain

Mooring systems are consisting of strength members like chain and wire. There are two main chain constructions:

- Stud-link chain (figure 5.1.a) has been used in shallow water for mooring of production platforms and it is strong, reliable and relatively easy to handle. The studs make handling of chain easy while laying and make chain more stable.

- Stud-less chain (figure 5.1.b) is preferred to use for permanent mooring lines. Compare to the stud-linked chain, the weight per unit of strength and construction cost decrease while the chain decay life increase. Chain size is shown with the nominal diameter "D" of the link (figure 5.1.a and 5.1.b). In mooring system design the specification and property of chain is important. The chain has a various grades.

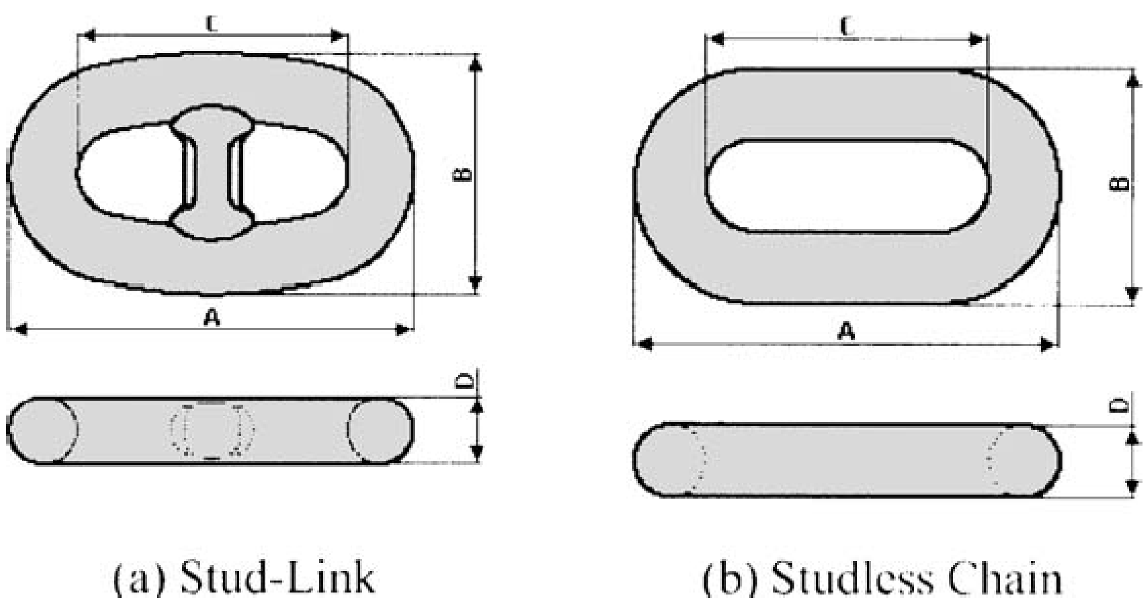

Figure 5.1 Stud-Link and Studless Chain (1)

5.2. Wire rope

Multi-strand or single-strand wire ropes are used for mooring lines. Strand is a form of individual wires which wound in a helical pattern. Flexibility and axial stiffness of the strand depends on the pitch of the helix form. The most common mooring components for temporary moorings are stud-linked chain and six-strand wire rope. The six-strand is a common type of multi-strand wire ropes which is mainly used in offshore. The wire types used in offshore are shown in figure 5.2. Mooring line ropes usually constructed of 12, 24, 37 or more wires per strand. To achieve higher strength the wires have staggered sizes. Multi-strand rope types are given as below:

- 6 x 7 Class: Seven wires per strand, usually used for rigging. Poor flexibility and fatigue life, excellent abrasion resistance. Minimum drum diameter/rope diameter (D/d) = 42.
- 6 x 19 Class: 16-27 wires per strand. Good flexibility and fatigue life and abrasion resistance. Common in lifting and dredging. Minimum D/d = 26-33.
- 6 x 37 Class: 27-49 wires per strand. Excellent fatigue life and flexibility, but poor abrasion resistance. Minimum D/d = 16-26.

Multi-strand wire ropes may have a fiber or a metallic core. This core can significantly support outer wires on drum and absorb shock loading in some operations. Independent wire rope core (IWRC) and wire-strand core (WSC) are two types of metallic core ropes. For heavy marine application IWRC are mostly used.

In permanent installations Single-strand ropes are usually used. The helix wire form which layers are wrapped in a different direction will provide torque balancing and prevent the rope from twisting when it is under load. Fatigue resistant in spiral strand is more than multi-strand rope. For improving the corrosion resistance, the wire can sheathed with polyurethane coating, adding zinc filler wires or using galvanized wires. Sheathing provides the best performance against damage.

Several construction methods are available and for better classification of the wire rope types some definitions can be illustrated as following:

Lay – manufacturing of wire rope by twisting of strands, or wrapping of wires to form a strand.

Cross Lay (figure 5.3) and **Equal Lay** (figure 5.4) - the lay terms of the wire used to form the strands.

Ordinary Lay (figure 5.5) - manufacturing method for a rope where the lay of the wires in the strand and the lay of the strands in the rope is opposite.

Lang's Lay (figure 5.6) - manufacturing method for a rope where the lay of the wires in the strand and the lay of the strands in the rope is same. Lang's lay has better wearing properties than ordinary lay because it tends to untwist. It is not used for mooring lines.

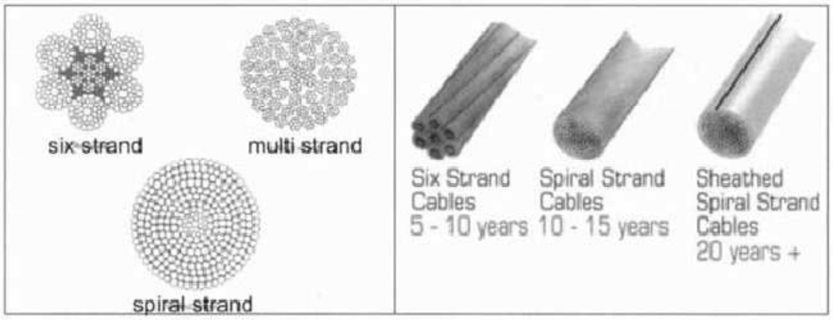

Figure 5.2 Wire rope construction (1)

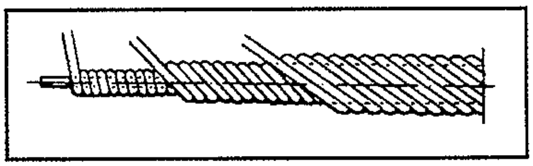

Figure 5.3 Cross Lay (7)

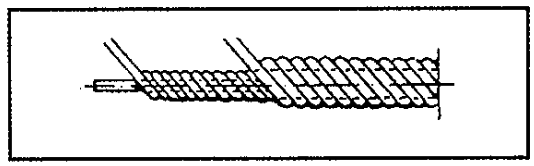

Figure 5.4 Equal Lay (7)

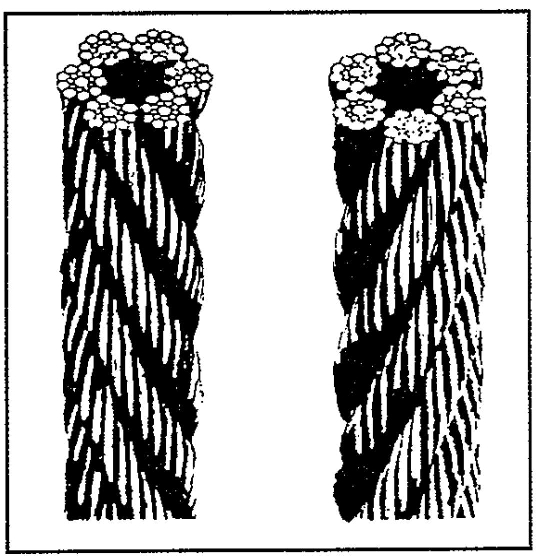

Figure 5.5 Ordinary lay (7)

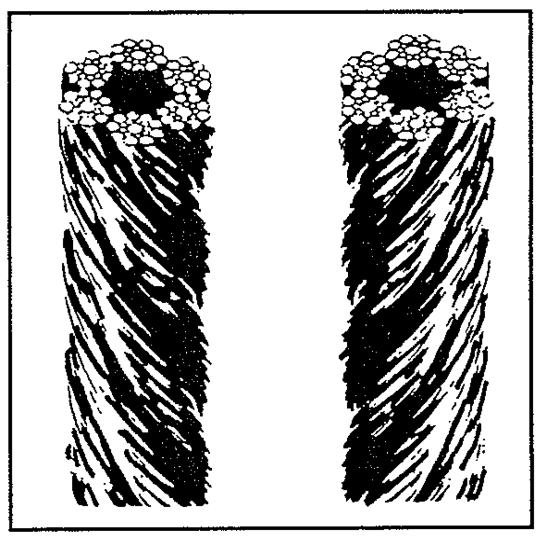

Figure 5.6 Lang`s lay (7)

5.3. Synthetic fiber ropes

Mooring ropes are usually made of HMSF, nylon, polyester, polypropylene, or a polyester/polypropylene mixture. Cable laid ropes are still in use but handling of it is difficult and if the handling is not proper it will be twist. 3-strand rope, 8-strand plaited rope and double braid rope are shown in figures 5.7, 5.8 and 5.9 respectively. Eight strand plaited ropes (square braid) are untwistable and flexible. Double braid or braid-on-braid ropes are consisting of a plaited inner rope covered by a tightly plaited sheath. These two can be from the same or different materials. Double braid ropes are often used for specific purposes.

Mooring ropes made of HMSF fibres have very low extension under load and higher breaking load than other synthetic fibres of the same size. Ropes manufactured with same size and material may have different life cycles.

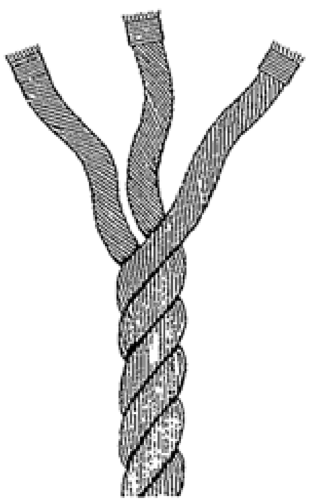

Figure 5.7 3-strand rope

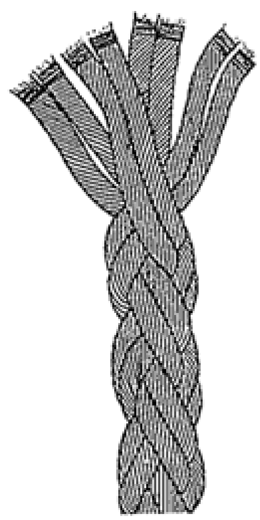

Figure 5.8 8-strand plaited rope

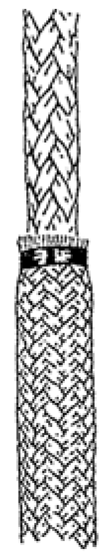

Figure 5.9 double braid rope (7)

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

Types of material used:

ARAMID fibre 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. Synthetic fibre ropes may used for HMSF ropes to get some elasticity.

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 fibre ropes, it is the heaviest fibre 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. (7)

6. Loading mechanisms

The different loading mechanisms act on moored floating vessel is shown in figure 6.1. For a specific weather condition, the excitation forces consist of current, wind and wave forces. Current are usually assumed constant and its spatial variation described by current profile and direction with depth. In preliminary design calculations, wind load is also considered constant and wind gust can generate slowly varying responses. Another component of time varying motions in the six body degree of freedom (surge, sway, heave, roll, pitch and yaw) is wave force. Wind gust forces can contribute to some of these motions as well.

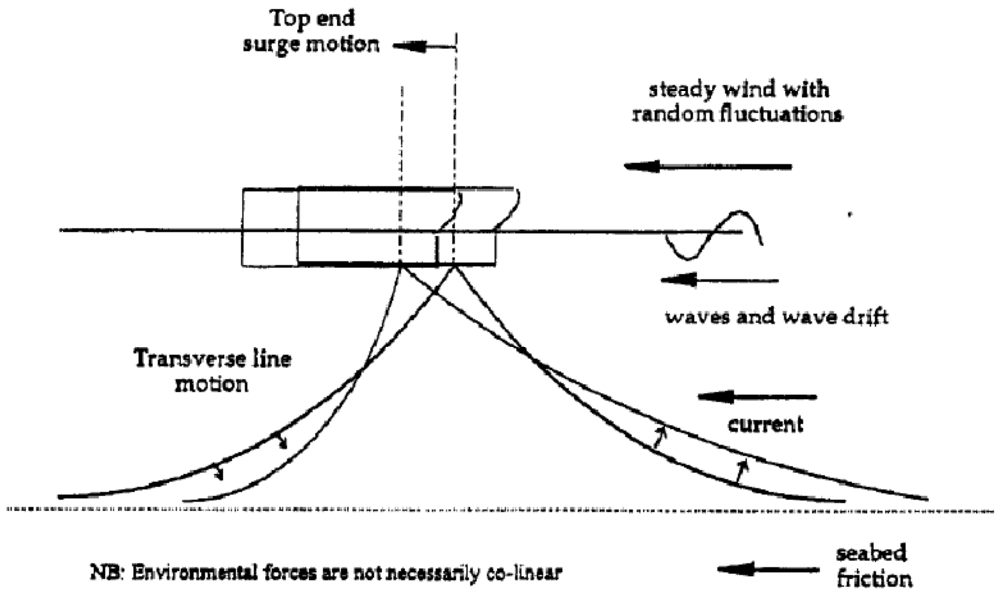

Figure 6.1 Environmental forces on a moored vessel in head conditions and transverse motion of catenary mooring line

In low wave frequencies, first-order motions and floating production structure responses are linked to drift motions. In particular, high mooring line loads obtained due to motion in the horizontal plane. This is because the drift force frequency corresponds to the natural frequency of moored vessel. Thus, it is necessary to define the level of damping of the system for controlling the resonant motion amplitude.

For a given significant wave height, the highest drift force will obtain for the shortest wave period. The wave period is very important.

Moreover, the forces on ship-shaped structures are increased if the vessel is not head on the waves. It happens if the wind and waves are not in the same direction and vessel has single point mooring.

Damping forces on a floating structure and the mooring systems are caused by several alternatives. The frictional drag between fluid (air) and the vessel obtained vessel wind damping and this effect can be small. Linearization procedures are used to obtain the damping coefficient. A viscous flow damping caused by current and the slowly varying motion of the vessel is also contributed in damping system. This provides lift and drag forces. Both viscous drag and eddy-making forces contribute. Large wave height increases the damping level. Wave drift damping on the vessel is related to changes in drift force by alteration of drift velocity. The current velocity considered as the structure slow drift velocity. The mean drift force will be larger when

a vessel is moving slowly towards the waves than it moves with the waves. Energy loss can be considered as slow drift motion damping.
These are several factors that influence on the overall mooring system damping:

- Hydrodynamic drag damping - the water depth, line pre-tension, weight and azimuth angle is important in measuring hydrodynamic drag damping. Also, transverse motion caused by a relative small horizontal translation of the vessel. Energy dissipation per oscillation cycle is shown by the transverse drag force. It can be used for measuring the line damping.
- Vortex-induced vibration - at a frequency close to the Strouhal frequency, unsteady forces increased due to vortex formation behind bluff bodies placed in a flow. These forces cause resonant response in a transverse direction and vortex formation in the shedding frequency to the natural frequency ratio, “lock-in”, can become synchronized. In-line drag forces significantly will increase in lock-in area. This effect is important for wire lines but not for chain.
- Line internal damping - frictional forces between individual wires or chain links known as material damping which can contribute to the total damping.
- Damping caused by seabed interaction - tension is reduced by soil friction that caused out-of-plane friction and suction. In deep water, this effect can be neglected for mooring lines but in-plane effects can considerably affect the peak tension values. (8)

7. Design methods

7.1. Mooring system design

Available design methods for catenary mooring lines are considered in this section.

7.2. Static design

In the initial design phases of mooring system that described by catenary line, static design is often used. For a single line of spread mooring system, Load/excursion characteristics are established. The fluid force on the line is ignored. Behaviors of the mooring line are explained by catenary equations and they can be used to derive mooring line tension and pattern.
Mooring line configuration and all symbols are shown in figure 7.1.

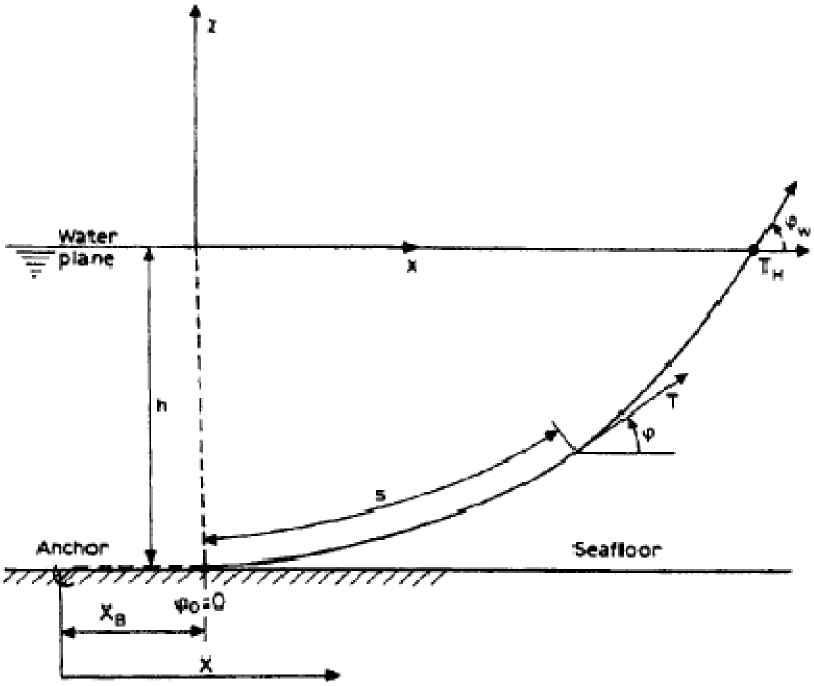

Figure 7.1 Cable line with symbols (1)

Seabed is assumed horizontal and bending stiffness effect and line dynamics is ignored. It is acceptable for mooring line (wire or chain) with small curvatures.

A single line element is shown in figure7.2. We have following terms (9):

- w: the constant submerged line weight per unit length
- T: line tension
- A: the cross-sectional area
- E: elastic modulus.
- D, F: mean hydrodynamic forces on the element and per unit length.

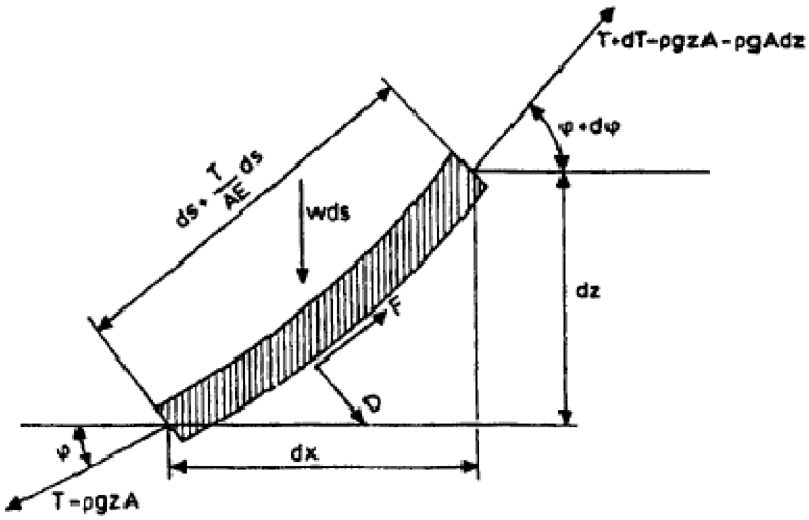

Figure 7.2 Force acting on an element of a mooring line (1)

As shown in figure 7.2. by considering in-line and transverse forcing we have (9):

$$dT - \rho gAdz = \left[w\sin\varphi - F\left(\frac{T}{EA}\right)\right]ds \tag{7.1}$$

$$Td\varphi - \rho gAzd\varphi = \left[w\cos\varphi + D\left(1 + \frac{T}{EA}\right)\right]ds \tag{7.2}$$

Mean hydrodynamic forces F and D together with elasticity in ignored for simplicity but when mooring lines are tight or for larger suspended line weight or deep waters, elastic stretch is very important and should be considered.

The suspended line length s and vertical dimension h can be obtained with the above assumptions as (9):

$$s = \left(\frac{T_H}{w}\right) sinh\left(\frac{wx}{T_H}\right) \tag{7.3}$$

$$h = \left(\frac{T_H}{w}\right)\left[cosh\left(\frac{w_x}{T_H}\right) - 1\right] \tag{7.4}$$

The top tension in the line can be written in terms of the catenary length s and depth d as:

$$T = \frac{w(s^2 + d^2)}{2d} \tag{7.5}$$

The vertical component of top tension in the line becomes:

$$Tz = ws \tag{7.6}$$

The horizontal component of tension in the line is given by:

$$T_H = T\cos\varphi_w \tag{7.7}$$

The assumption made for above analysis is that mooring line at the lower end is horizontal. This is same as the case that gravity anchors with no uplift is applied.

The forces applied on the vessel from each catenary line are calculated for this analysis. The line lengths and coordinates of end point of the line on the seabed and vessel and elasticity are known. The horizontal restoring and vertical forces are obtained by calculate the summation of forces for all lines in the spread mooring. For calculating the largest restoring force and tension in the line the vessel should displaced in prescribed horizontal distances in each direction. Results of typical analysis are shown in figure 7.3. The resultant static component of vessel offset from the horizontal axis is obtained by applying the component of environmental force from wind, current and wave drift effects to the vertical axis of this diagram. A corresponding linear stiffness C_t of the mooring system in the relevant direction measured from the force curve slope at this offset and this coefficient can be used in this equation:

$$C_t x = F_x(t) \tag{7.8}$$

x: co-ordinate for horizontal degree of freedom (surge or sway)

F: force

C_t : linear stiffness

Then the maximum dynamic offset caused by the wave and drift frequency effects is calculated.

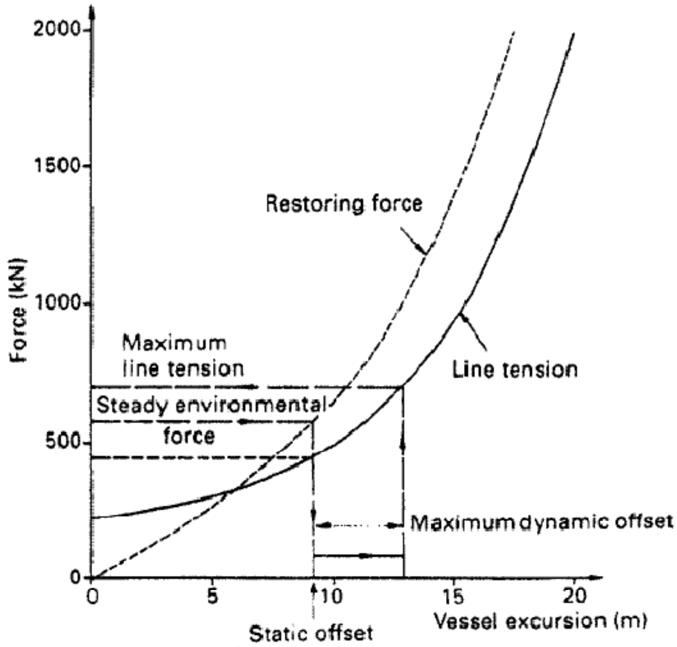

Figure 7.3 Restoring force and most loaded line tension against excursion for a catenary mooring system (1)

The line lying on the seabed should not have upward component of force at the anchor. The calculation will repeat with increased length when the mooring line force is insufficient.

The largest load exist in the mooring lines is read off and compared with the allowable breaking strength of the line. If the allowable ratio is too high, the line pre-tension, material specification for each line and the line end co-ordinates or number of lines will change and calculation will repeat.

When the mooring system is designed for intact condition, the calculation should be done for damage condition. Similar checks should be done for damage case when the most loaded line in broken. This method has disadvantage. Assuming the uni-directional environment is conservative and caused uncertainties which can be balanced by applying large safety factors.

In addition main advantages of the dynamics are missing from this methodology. (1)

7.3. Quasi static design#

This method is more complex. Generally, two calculation techniques are used here:

- «A time-domain simulation used for the wave-induced vessel forces and responses at wave and drift frequency, while steady wind and current forces applied and the mooring stiffness curve used without considering line dynamics. »

- «A frequency response method is applied when the mooring stiffness curve is assumed linear and low-frequency dynamic responses to both wave drift and wind gust effects are calculated as a linear single degree of freedom system. »

The static and quasi-static design fundamental differences are:

- Quasi-static analysis: usually the catenary stiffness in the motion equation at each horizontal offset is non-linear. The linear stiffness characteristics may be assumed for stiff catenary or taut mooring.
- Equations of motion are integrated in the time domain. The effect of added mass and damping are included and influence of mooring system and vessel are also considered.
- Frequency domain solutions are feasible but assumptions made by linearisation of stiffness and damping is crucial.

The following equation should be solved:

$$(m + A)\ddot{x} + B\dot{x} + B_v\dot{x}|\dot{x}| + C_t x = F_x(t) \quad (7.9)$$

m: vessel mass

A: added mass

B: linear damping

B_v: viscous damping

F_x: the time dependent external forcing

x: the motion in each degree of freedom, Coupling between the motions can also be included.

For the low frequency responses, the statistical data should be made by observing minimum of 18 hour full-scale behavior and simulation should be done to obtain a proper answers. (8)

7.4. Dynamic design

In design of mooring lines, full dynamic analysis methods are commonly used but for mooring line damping values there is no general agreement. In deep water, it may have effect on vessel responses and line loads. The methodology is described as follows:

Static design with non-linear time domain solutions has to be established about this initial shape. The line is mostly decomposed into a number of linear segments. The distributed mass plus added mass which is lumped at end nodes is exceptions.

Platform motions are calculated separately from line dynamics estimation. Though in deep water, the effect of interaction between moored platform and mooring lines has been considered. Moreover coupled platform mooring analysis methods should be applied. In this case, the effect of line dynamic on the platform motion is considered in a time domain solution. In the dynamic methods the additional loads from mooring system, restoring forces and hydrodynamic damping effects of motion between the line and fluid are counted. Also, inertial effects between the line and fluid are included while the impact is neglected. For modeling of small segments of line in the simulations the lumped mass finite element or finite difference schemes are used. The line shape is changed from the static catenary profile due to the water resistance. Time domain analysis which is computationally intensive is carried out. Challenges consist of:

- Time steps must be considered small to cover wave-induced line oscillations.
- Runs must be considered long enough to allow for the vessel drift oscillation period (i.e. in deep water may be of the order of 5 min).
- In a typical mooring system design, several test cases should be considered because of the multi-directional weather factor.

Line top-end oscillation must be included for the vessel motion in a combined wave and drift frequencies. Otherwise, advantages of contribution of line damping may be neglected or dynamic tension component may be underestimated. In some cases, top tension duplicated due to line dynamics in comparison to the static line tension. Moreover, damping levels with regard to multiple factor such as water depth, line make up, offsets and top-end excitation differ in large order.

Nowadays hybrid methods are introduced. These methods are time domain simulation but also simplistic assumptions established for the instantaneous line shape. This approach has some advantages but more research should be done to provide these methods applicable in the design. Frequency domain methods which are more efficient are also being developed. These methods approximately include line dynamics. In large line oscillations due to fluid drag force, strong nonlinearities occur so these methods are not working well enough yet. (1)

8. Standards and guidelines

Several standards and guidelines are provided for design of mooring systems of production platforms.

Standards and guidelines for design of mooring systems are as below:

- 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)
- DNV-OS-E301 (Det Norske Veritas- Position Mooring)
- DNV-RP-C205 (Det Norske Veritas- Environmental Conditions and Environmental Loads)
- API RP 2SK(American Petroleum Institute- Recommended Practice for Design and Analysis of Station-keeping Systems for Floating Structures)
- GL Noble Denton (Guidelines for Moorings)

All above mentioned standards are represent the guidelines and acceptable criteria for design of mooring systems in offshore industry. 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. The external actions generally consist of wind, wave, current on the floating structure and mooring system. The station keeping systems are consisting of permanent and mobile mooring systems. Also, the standard is including requirements for manufacturing of mooring components and is applicable to all aspects of the system life cycle and considerations for inspections of mooring system in service. The requirement of standard mainly deals with spread mooring systems and single mooring systems which are composed of steel chain, wire rope and synthetic fibre ropes. ISO 19901-7 is a preferable standard for design of all mooring systems. API Recommended Practice 2SK (RP 2SK) is includes extensive guidance which is not included in the International Standard ISO 19901-7.

We can use one of these standards for design of mooring system and referring to others for subjects that was not cover in main standard.

In this thesis all criteria and coefficients are found according to DNV-OS-E301 and DNV-RP-C205.

DNV-OS-E301 offshore standard includes criteria, technical requirements and guidelines for design and construction of position mooring systems. The standard is appropriate for column-stabilised units, ship-shaped units, loading buoys and deep draught floaters (DDF) or other floating bodies with catenery mooring, semi-taut and taut leg mooring system. The aim of this standard is to give a uniform level of safety for mooring systems, consisting of chain, steel wire ropes and fibre ropes.
DNV-RP-C205 recommendation practice is consisting of guidelines and regulations for modeling, analysis and prediction of environmental conditions and environmental loads acting on structure. The loads are wind, wave and current. Other loads are induced on slender members due to Wave and current. The hydrodynamic force on slender member having cross sectional dimensions is decomposed to tangential and normal force. The wave load maybe calculated by Morison equation which is sum of inertia force proportional to acceleration and a drag force proportional to the square of velocity. Non dimentional drag and added masss coefficients can be defined for tangentinal and normal hydrodynamic forces according to DNV-RP-C205.

The drag coefficient C_D is the non-dimensional drag force:

$$C_D = \frac{f_{drag}}{\frac{1}{2}\rho D V^2} \qquad (8.1)$$

Where:

f_{drag} = sectional drag force [N/m], The drag force f_{drag} is decomposed in a normal force f_N and a tangential force f_T.
ρ = fluid density [kg/m^3]
D = diameter (or typical dimension) [m]
v = velocity [m/s]

The added mass coefficient CA is the non-dimensional added mass:

$C_A = \frac{m_a}{\rho A}$ (8.2)

Where:

m_a = the added mass per unit length [kg/m]
A= cross-sectional area [m^2]
ρ = fluid density [kg/m^3]

The Analytical added mass coefficient for two-dimentional and three-dimensional bodies in infinite fluid are summarized in appendix D of DNV-RP-C205. The drag coefficient for non-circular cross section in steady flow are summerized in appendix E of DNV-RP-C205.

9. Static and dynamic response analysis

In this thesis the static and dynamic analysis will be carried out by RIFLEX software. The software in mainly used for analysis of slender structures like risers.

Breif description about RIFLEX software will be given below.

9.1. RIFLEX overview

RIFLEX was developed as a tool for analysis of flexible marine riser systems, but is as well used for any type of slender structure, such as mooring lines, umbilicals, and also for steel pipelines and conventional risers.

These slender structures may be characterized by(10):

- Small bending stiffness
- Large deflection
- Large upper end motion excitation
- Nonlinear cross section properties
- Complex cross section structure

The program computes static and dynamic characteristics of the structure and is based on a nonlinear finite element formulation.

The program system consists of five programs or modules communicating by a file system as shown in Figure 9.1.

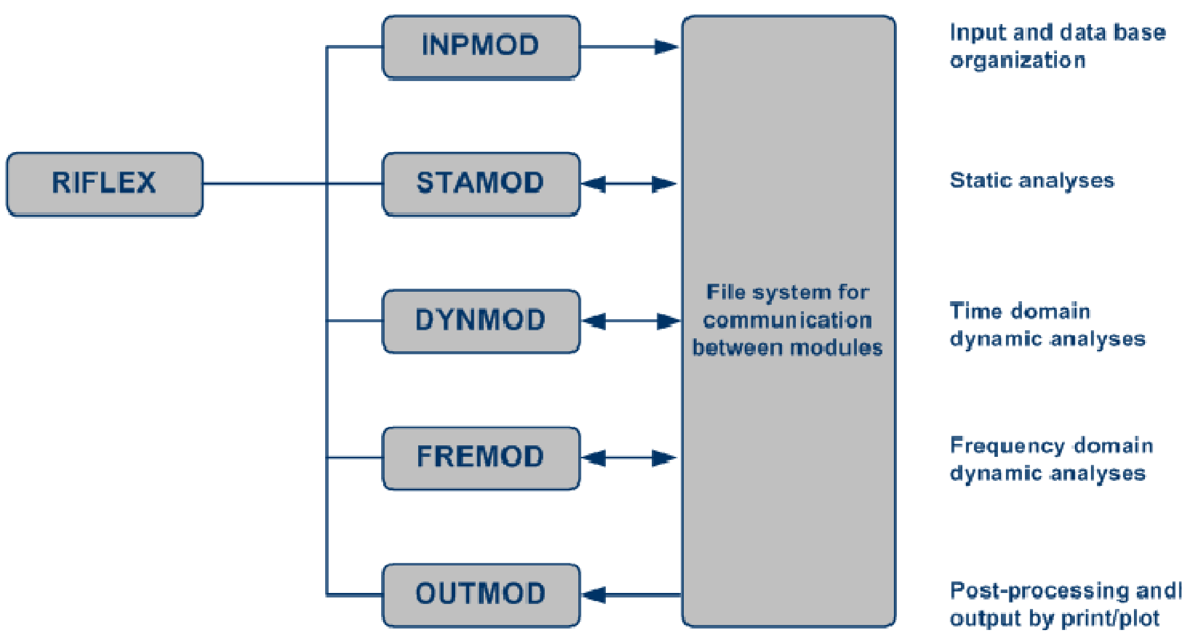

Figure 9.1 Structure of program system (10)

9.1.1. INPMOD module

The most input data i.e. material properties and environmental loads reads in INPMOD module and a data base will be organaized for use during subsequent analyses.

9.1.2. STAMOD module

The STAMOD module exerts diffrent types of static analyses. The results will be used in parameter studies directly and also as a initial data for a dynamic analysis.
based on input data given in INPMOD, STAMOD will generate Element mesh, stressfree configuration and key data for finite element analysis.

9.1.3. DYNMOD module

The DYNMOD module performed time domain dynamic analyses based on the final static data, environment data and data to define motions applied as forced displacements in the analysis. It is possible to carry out several dynamic analyses without rerun of INPMOD and STAMOD. Response time series are stored on file for further postprocessing by OUTMOD and PLOMOD. In addition to dynamic response, natural frequencies and modeshapes can be calculated.

9.1.4. FREMOD module

FREMOD module may be used to perform frequency domain analyses with stochastic linearization of the quadratic Morison drag term. The structural properties and the static equilibrium state must be previously calculated by STAMOD and stored by DYNMOD.

9.1.5. OUTMOD module

OUTMOD performs postprocessing of selected results generated by STAMOD and DYNMOD. It is possible to store plots on a separate file for graphic output in the PLOMOD module. It is also possible to export time series via a standardized file format for further postprocessing by general purpose statistical analysis program (STARTIMES).

9.1.6. PLOMOD module

Interactive plotting module for graphic presentation of plots generated by OUTMOD. An animation tool is available for visualization of the dynamic behaviour of the complete system (mooring lines, risers, vessel, waves).

9.2. Modelling

This section will give a breif description of principles for modelling and analysis in RIFLEX.
There are two systems used for risers modeling,general and standard systems.
General system discribes geometry and boundry conditions. The system topology is in general described in terms of points that are denoted as supernodes. Supernodes are classified as free, fixed or prescribed depending on their boundary condition modelling. Supernodes are connected by simple lines. The line is specified in terms of sequence of segments with homogenous cross sectional properties. Cross sectional component type, length and number of elements to be used for finite element discretization are specified for each segment (see figure 9.2.).

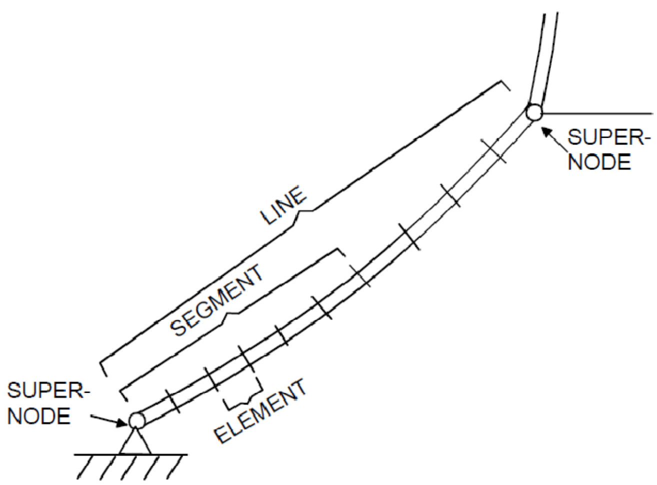

Figure 9.2 System modeling (10)

Standard system In order to simplify the system topology definition for commonly used configurations, a selection of standard systems for single riser are provided in RIFLEX: (10)

SA - The Steep Wave, Steep S and Jumper flexible riser with One point seafloor contact.
SB - Catenary, Lazy Wave and Lazy S flexible riser with Seafloor tangent and/or additional seafloor attachment point.

SC - Riser during installation with free lower end.

SD - Buoyed riser with free upper end.

CA - Parrallel coupled riser

CD – Branched riser systems

The riser is modeled with respect to general and standard system and the geometry and property of riser defined by combination of supernodes and elements. material property and cross sectional data will be given to elemetns.The boundary condition have to be defined. The seafloor contact is modelled by bilinear stiffness. The stiffness is discretized and implemented as springs at the nodal points that may touch the seafloor.

The horizontal contact force with the seabed will be modeled as independent with respect to axial and lateral direction. The friction forces will follow coulomb friction.

$$F = \mu N \tag{9.1}$$

F: Total friction force
N: normal force from riser weight
μ : friction parameter

the environmental loads will be modelled by using inertia and drag coeifficients with possibility of using second order drag terms. Current forces are assumed constant with respect to time and are modelled by using constant velocities at given depths. The forced motion at the contact point between floater and riser is modelled using transfer function for the floater motion pattern.

9.3. Analysis preface

The analysis will be done for a mooring line connected to a suezmax vessel. Two conditions, Ballasted and loaded will be considered for suezmax vessel with 15 deg heading relative head waves. Influence of the vessel in analyses will be included by using a transfer function developed by APL Company. RAO’s for vessel are given for two water depths 100m and 1000m. The RAO’s for 1000 m water depth can be applied for all water depths above 300m.

Static and dynamic analysis will be done by using RIFLEX software based on regular waves for two mooring line compositions consist of chain and steel wire ropes in water depths 100m and 400 m.

Two sets of waves are to be considered:

a) H=15 m, T=9,10,11,12,13,14,15 s
b) H=30 m, T=13,14,15,16,17 s

The following mooring line compositions will be provided and applied:

a) Chain and steel wire rope for water depth 100 m
b) Chain and steel wire ropes for water depth 400 m

The mooring line properties and dimensions are given by APL Company.

Static tension in the mooring line shall be 15%, 30% and 45% of MBL (minimum breaking load) and they will be obtained by changing vessel offset. For considering the influence of hydrodynamic force on system, drag and added mass coefficients will be calculated according to DNV-OS-E301 and DNV-RP-C205.

The analysis will concentrate on displacement and the effective tension in mooring line. bending moment and curvature of line are neglected.

One of the input file in RIFLEX format is given in appendix A and the output of this case in provided in appendix B. all input files and results for all cases can be found in the attached CD.

9.3.1. Vessel Particulars and Mooring Line Description

➢ **Vessel Particulars:**

Table 9-1 Suezmax vessel particulars (APL)

Particular	Symbol	Unit	Ballast	Loaded
Length between perpendiculars	L_{PP}	m	258	
Breadth moulded	B	m	46	
Depth	D	m	26.6	
Mooring line connection fore of midship		m	90	
Mooring line connection below vessel keel		m	2.5	
Displacement	Δ	tonnes	109 610	185 090
Draught	T	m	11.34	18.17
Longitudinal COG fore of midship	LCG	m	8.586	3.685
Vertical COG above BL with FS effect	VCG	m	14.593	16.296
Radii of gyration, roll	R_{44}	m	18.40	16.10
Radii of gyration, pitch	R_{55}	m	67.08	59.34
Radii of gyration, yaw	R_{66}	m	67.08	59.34

RAO's are given for water depth 100 m and 1000 m for ballasted and loaded conditions in RIFLEX format. The files are attached in appendix A.

➢ **Mooring Systems:**

Case 1: Water depth = 100 m

Table 9-2 Case 1-mooring line descriptions (APL)

Segment number (anchor to turret)	Segment type	Building Length [m]
1	145 mm Studless Chain	200
2	135 mm Steel Wire Rope	500
3	145 mm Studless Chain	400
4	135 mm Steel Wire Rope	180

Minimum Breaking Load: 13800 KN

<u>Studless Chain:</u>

- Nominal rod diameter = 145 mm
- Mass = 420.5 kg/m
- Submerged weight = 3.586 KN/m
- Axial stiffness = 1639 MN

<u>Steel Wire Rope:</u>

- Nominal diameter = 135 mm (incl. sheathing)
- Mass = 72.1 kg/m
- Submerged weight = 0.564 KN/m
- Axial stiffness = 1283 MN

<u>Case 2:</u> Water depth = 400 m

Table 9-3 Case 2-mooring line descriptions (APL)

Segment number (anchor to turret)	Segment type	Building Length [m]
1	145 mm Studless Chain	700
2	135 mm Steel Wire Rope	450
3	MLBE (Mooring Line Buoyancy Element)	5
4	135 mm Steel Wire Rope	200

Minimum Breaking Load: 13800 KN

<u>Studless Chain:</u>

- Nominal rod diameter = 145 mm
- Mass = 420.5 kg/m
- Submerged weight = 3.586 KN/m
- Axial stiffness = 1639 MN

<u>Steel Wire Rope:</u>

- Nominal diameter = 135 mm (incl. sheathing)
- Mass = 72.1 kg/m
- Submerged weight = 0.564 KN/m
- Axial stiffness = 1283 MN

<u>MLBE:</u>

- Building length in the line model shall be 5 m, but the MLBE is a circular cylinder with actual length of 8 m and diameter of 3.5 m. The actual dimensions shall be used to establish drag and added mass. The MLBE length axis is in the line direction, i.e. in the same direction as the modelled 5 m element.

- Mass = 40.0 t
- Net buoyancy = 400.0 KN

9.3.2. Hydrodynamics

This analysis has been done with two sets of regular waves and no current:

a) H=15 m, T=9,10,11,12,13,14,15 s

b) H=30 m, T=13,14,15,16,17 s

The nondimensional hydrodynamic force coeifficents (drag and added mass) are defined as table 9.4.

Table 9-4 The nondimensional hydrodynamic force coeifficents (APL)

Segment type	Cdn	Cdt	Cmn	Cmt
145 mm Studless Chain	1.5	0.2	1.0	0.2
135 mm Steel Wire Rope	1.2	0.0	1.0	0.0
MLBE (Mooring Line Buoyancy Element)	0.8	0. 8	0.8	0.8

Cdt - nondimensional quadratic tangential drag coefficient

Cdn - nondimensional quadratic normal drag coefficient

Cmt - nondimensional tangential added mass coefficient

Cmn - nondimensional normal added mass coefficient

9.3.3. Seabed conditions

Table 9-5 Seabed conditions (APL)

Vertical stiffness parameter	100	(kN/m^2)
Horizontal stiffness parameter,axial	10	(kN/m^2)
Horizontal stiffness parameter,lateral	100	(kN/m^2)
Horizontal friction parameter,axial	0.7	(---)
Horizontal friction parameter,lateral	0.7	(---)

9.4. Analysis results

9.4.1. Case 1- ballasted condition

9.4.1.1. Static analysis

Static analysis was carried out for mooring line case 1 when the tension on line is 15%, 30% and 45% of MBL (minimum breaking load), two sets of regular waves with different wave period and wave heights applied on system and vessel is in the ballasted condition. Mooring line shapes in XZ plane are shown in figures 9.3., 9.4., 9.5. With comparison between these figures, when the tension on the mooring line increased the seafloor interaction will decreased.

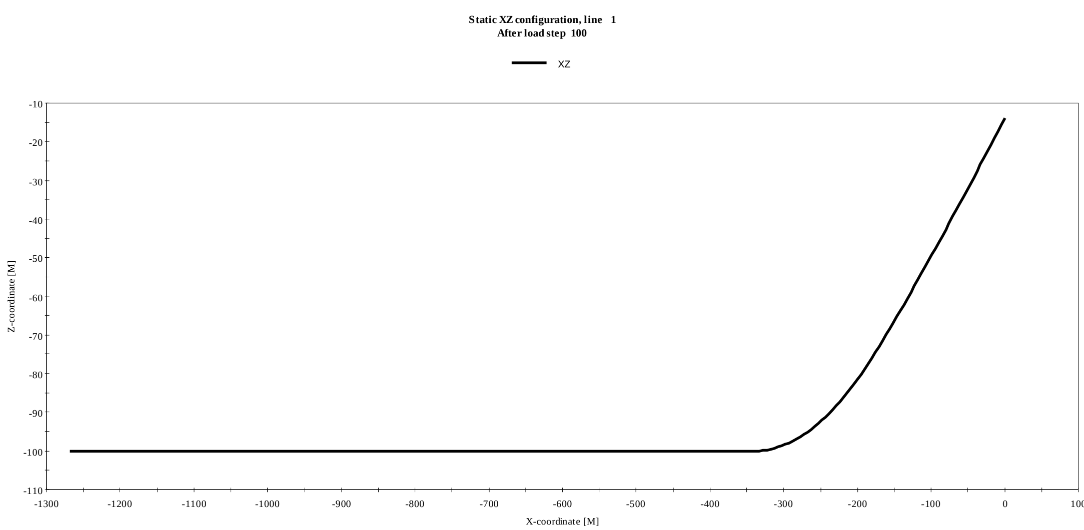

Figure 9.3 Mooring line shape in XZ plane with tension 15% MBL-case1-ballasted

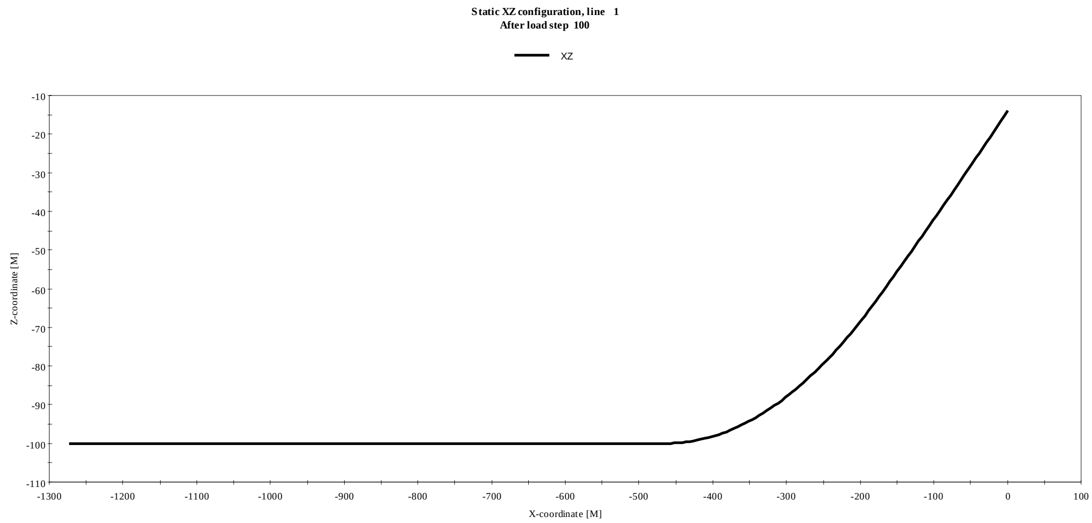

Figure 9.4 Mooring line shape in XZ plane with tension 30% MBL-case1-ballasted

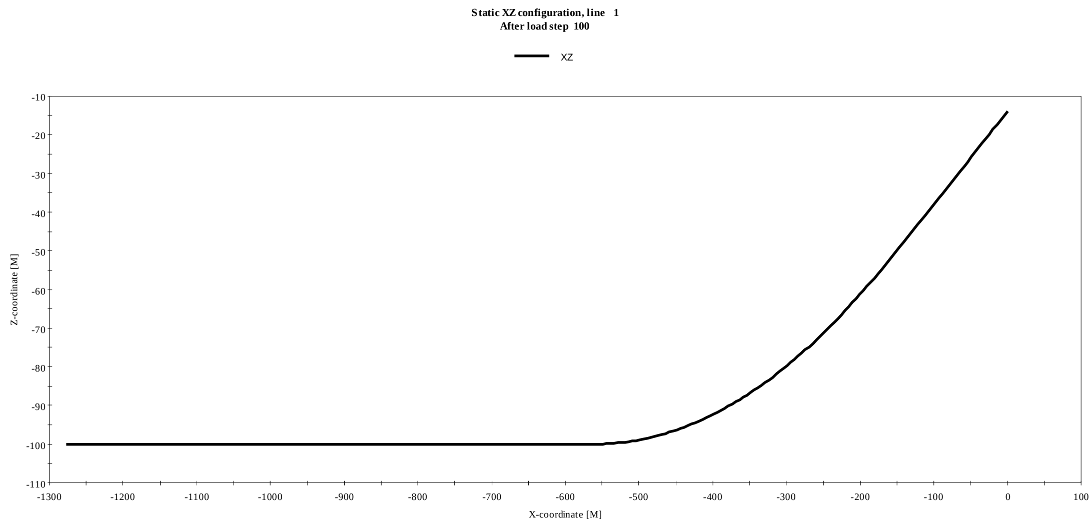

Figure 9.5 Mooring line shape in XZ plane with tension 45% MBL-case1-ballasted

9.4.1.2. Dynamic analysis

The maximum and minimum effective tension of the mooring line for three line configuration when the tension applied on line is 15%, 30% and 45% are shown below. Also, in this section all line displacements are summerized in following tables.

9.4.1.2.1. Mooring line with tension 15%MBL- Regular wave H=15m, T=9-15s

For mooring line with tension 15%MBL, the maximum and minimum effective tension in regulare waves with wave height 15m and periods from 9s to 15s are shown in fgures 9.6 to 9.12.

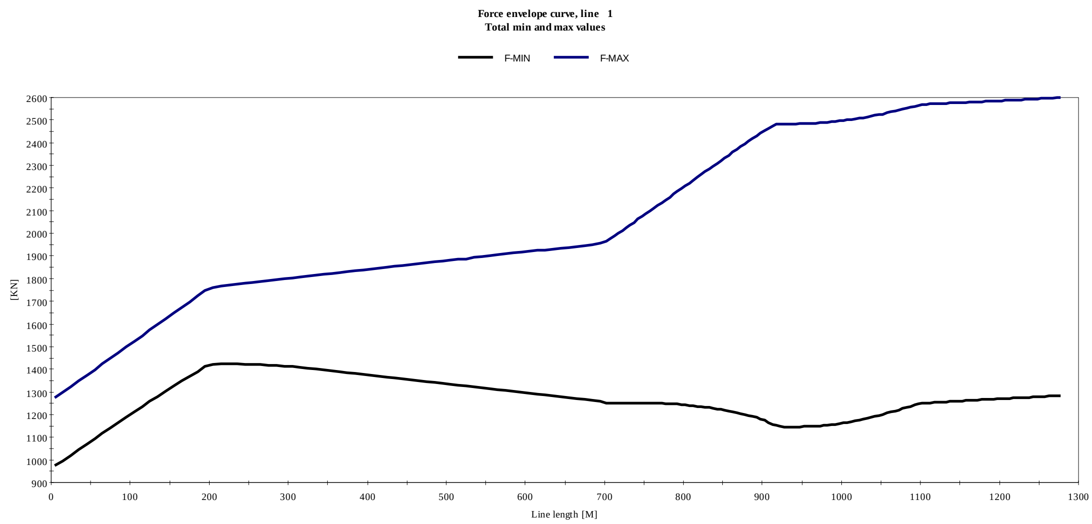

Figure 9.6 Maximum and minimum effective tension in mooring line – case1-tension 15%MBL –ballasted condition - H=15m, Period 9s

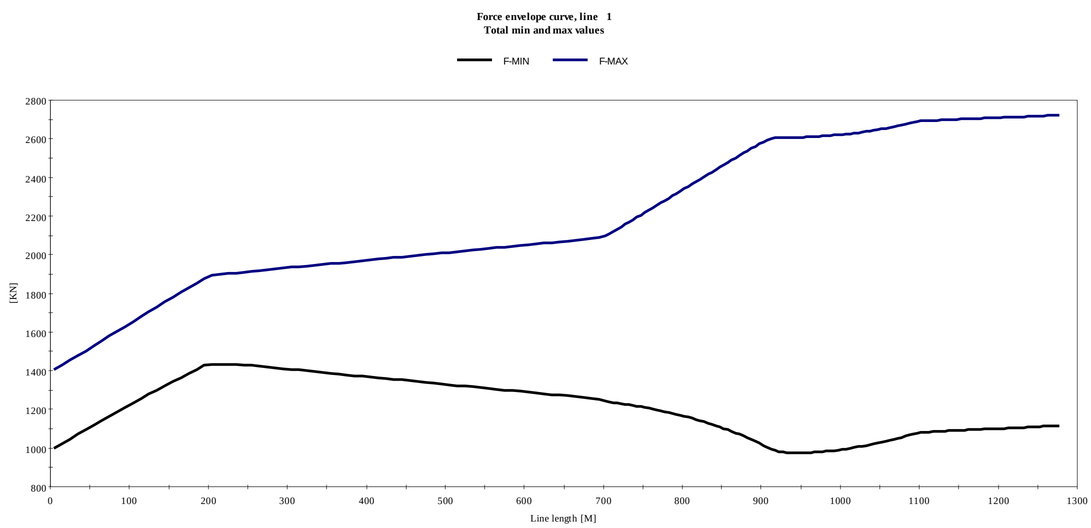

Figure 9.7 Maximum and minimum effective tension in mooring line – case1-tension 15%MBL –ballasted condition - H=15m, Period 10s

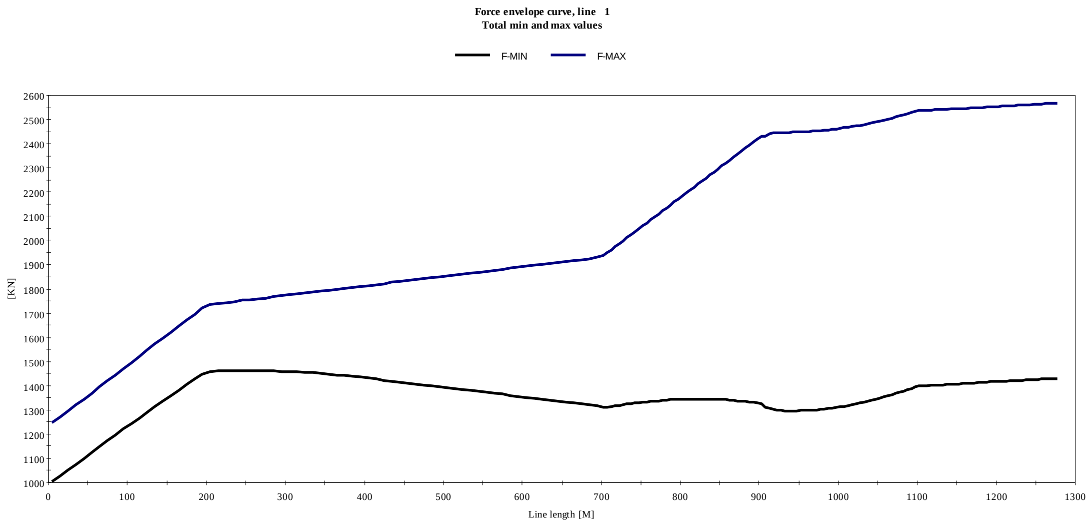

Figure 9.8 Maximum and minimum effective tension in mooring line – case1-tension 15%MBL –ballasted condition - H=15m, Period 11s

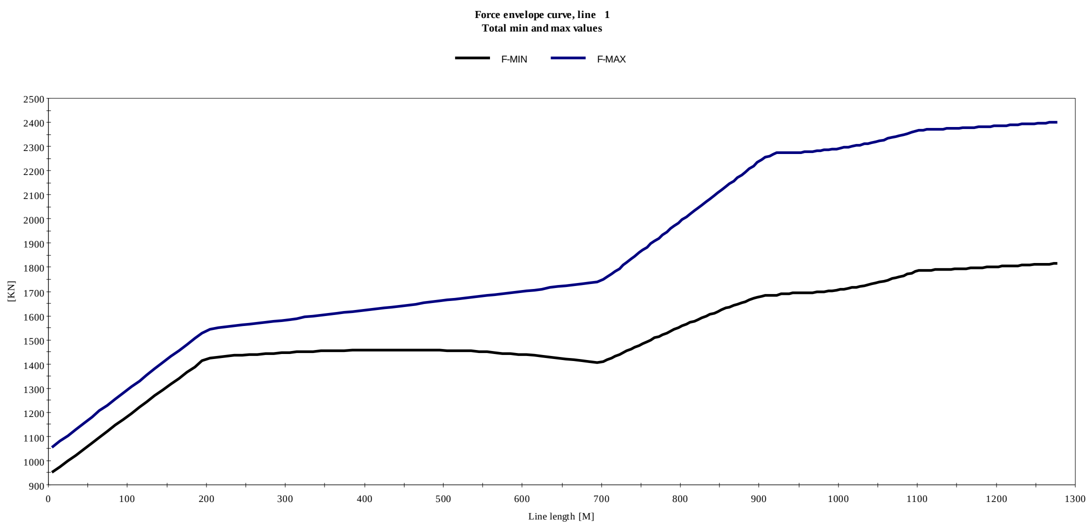

Figure 9.9 Maximum and minimum effective tension in mooring line – case1-tension 15%MBL –ballasted condition - H=15m, Period 12s

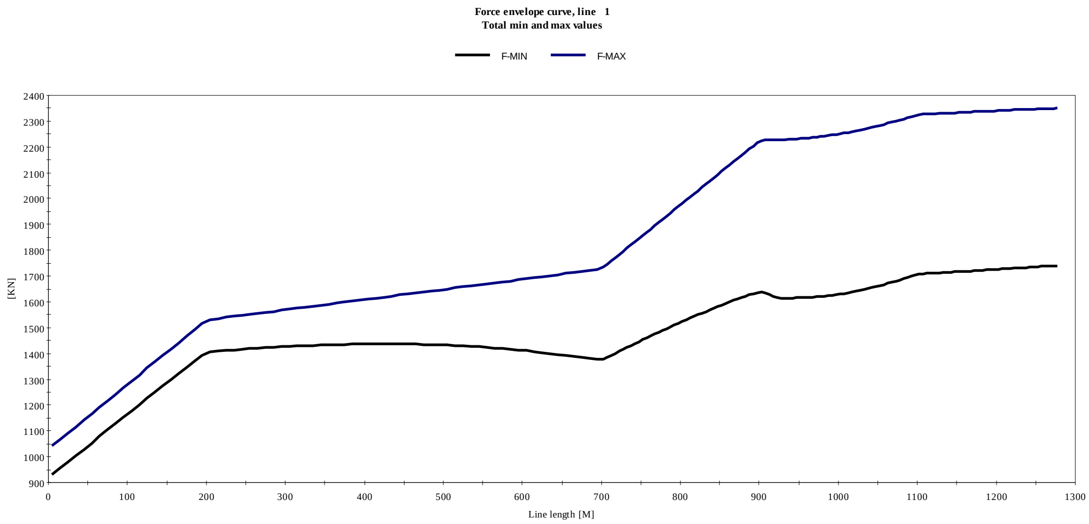

Figure 9.10 Maximum and minimum effective tension in mooring line – case1-tension 15%MBL –ballasted condition - H=15m, Period 13s

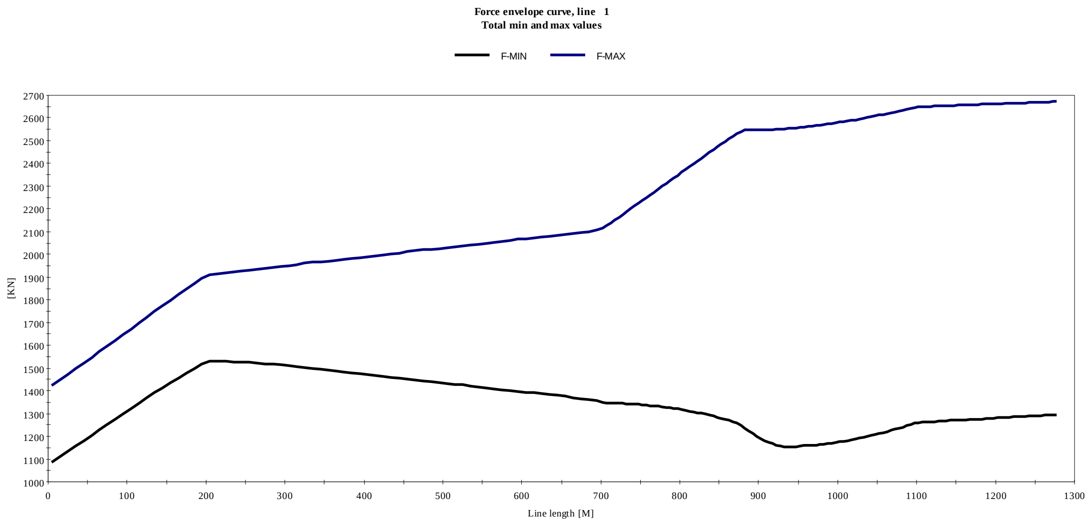

Figure 9.11 Maximum and minimum effective tension in mooring line – case1-tension 15%MBL –ballasted condition - H=15m, Period 14s

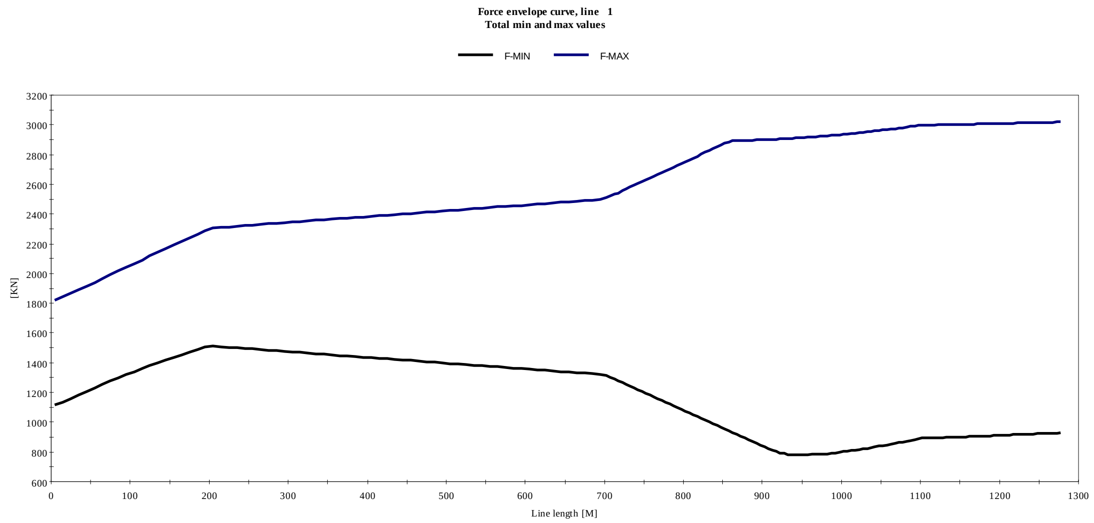

Figure 9.12 Maximum and minimum effective tension in mooring line – case1-tension 15%MBL –ballasted condition - H=15m, Period 15s

The maximum and minimum effective tension in mooring line and the maximum and minimum line displacement in X, Y and Z directions are summarized in tables 9.6 and 9.7.

The following results and behaviours are observed:

- The lowest value for minimum dynamic axial force is obtained in highest seastate with wave height 15m and wave period 15s.
- The highest value for maximum dynamic axial force is obtained in highest seastate with wave height 15m and wave period 15s.
- The lowest value for minimum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 15m and wave period 15s.
- The highest value for maximum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 15m and wave period 15s.

Table 9-6 Force envelope curves for case1-tension 15%MBL –ballasted-seastate case 1

SEASTATE	FORCE ENVELOPE CURVES		
	AXIAL FORCE		
	MIN DYNAMIC	STATIC FORCE	MAX DYNAMIC
H=15m,T= 9s	-7.87E+02	2.06E+03	6.02E+02
H=15m,T=10s	-9.58E+02	2.06E+03	7.34E+02
H=15m,T= 11s	-6.36E+02	2.06E+03	5.74E+02
H=15m,T= 12s	-2.44E+02	2.06E+03	3.83E+02
H=15m,T= 13s	-3.20E+02	2.06E+03	3.69E+02
H=15m,T= 14s	-7.79E+02	2.06E+03	7.51E+02
H=15m,T=15s	-1.15E+03	2.06E+03	1.15E+03

Table 9-7 Displacement envelope curves for case1-tension 15%MBL –ballasted-seastate case 1

SEASTATE	DISPLACEMENT ENVELOPE CURVE					
	X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC
H=15m,T= 9s	-4.96E-01	9.26E-01	-4.00E-01	3.56E-01	-5.22E+00	4.14E+00
H=15m,T=10s	-5.50E-01	1.05E+00	-6.11E-02	8.51E-02	-6.23E+00	5.02E+00
H=15m,T= 11s	-6.03E-01	9.56E-01	-5.86E-01	5.84E-01	-5.68E+00	5.13E+00
H=15m,T= 12s	-1.48E+00	1.79E+00	-1.10E+00	1.06E+00	-6.74E+00	6.80E+00
H=15m,T= 13s	-2.54E+00	3.00E+00	-1.49E+00	1.37E+00	-8.04E+00	8.14E+00
H=15m,T= 14s	-3.52E+00	4.02E+00	-1.80E+00	1.56E+00	-8.72E+00	8.85E+00
H=15m,T=15s	-4.30E+00	4.74E+00	-2.14E+00	1.62E+00	-8.89E+00	9.06E+00

9.4.1.2.2. Mooring line with tension 15%MBL- Regular wave H=30m, T=13-17s

For mooring line with tension 15%MBL, the maximum and minimum effective tension in regulare waves with wave height 30m and periods from 13s to 17s are shown in fgures 9.13 to 9.17.

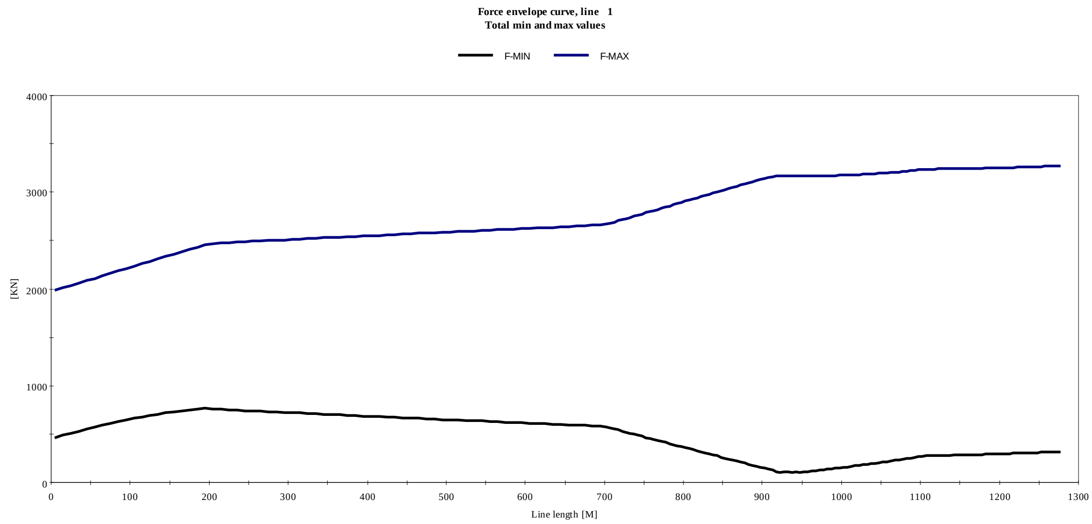

Figure 9.13 Maximum and minimum effective tension in mooring line – case1-tension 15%MBL –ballasted condition - H=30m, Period 13s

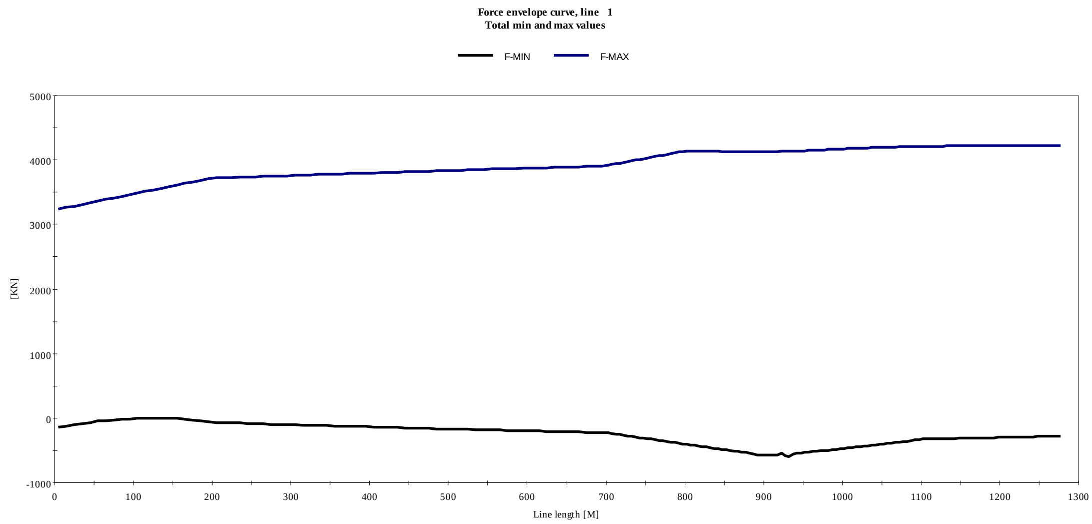

Figure 9.14 Maximum and minimum effective tension in mooring line – case1-tension 15%MBL –ballasted condition - H=30m, Period 14s

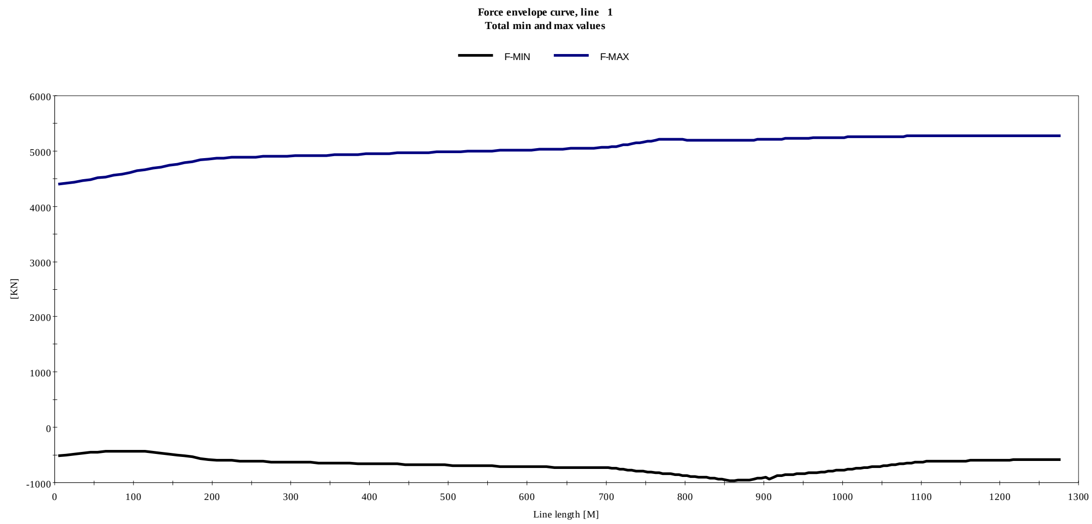

Figure 9.15 Maximum and minimum effective tension in mooring line – case1-tension 15%MBL –ballasted condition - H=30m, Period 15s

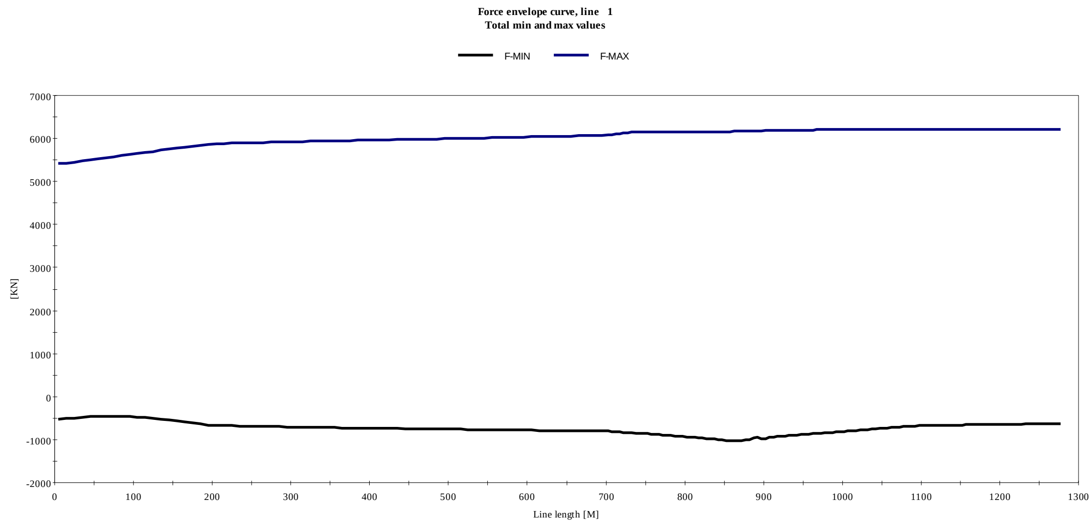

Figure 9.16 Maximum and minimum effective tension in mooring line – case1-tension 15%MBL –ballasted condition - H=30m, Period 16s

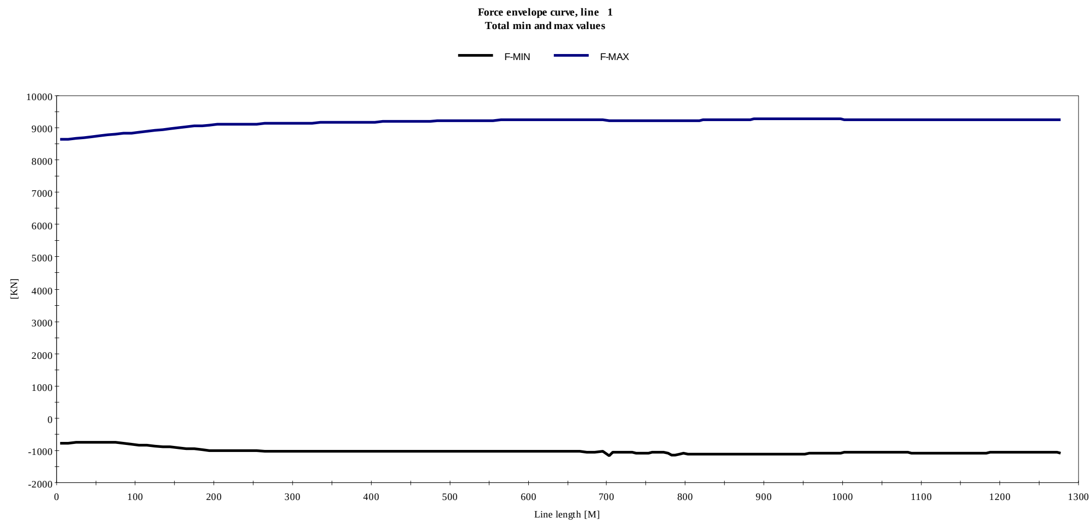

Figure 9.17 Maximum and minimum effective tension in mooring line – case1-tension 15%MBL –ballasted condition - H=30m, Period 17s

The maximum and minimum effective tension in mooring line and the maximum and minimum line displacement in X, Y and Z directions are summarized in tables 9.8 and 9.9.

The following trends and behaviours are extracted:

- The lowest observed value for minimum dynamic axial force is obtained in highest seastate with wave height 30m and wave period 17s.
- The highest value for maximum dynamic axial force is obtained in highest seastate with wave height 30m and wave period 17s.
- The lowest value for minimum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 30m and wave period 17s.
- The highest value for maximum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 30m and wave period 17s.

Table 9-8 Force envelope curves for case1-tension 15%MBL –ballasted-seastate case 2

SEASTATE	FORCE ENVELOPE CURVES		
	AXIAL FORCE		
	MIN DYNAMIC	STATIC FORCE	MAX DYNAMIC
H=30m,T= 13s	-1.83E+03	2.06E+03	1.32E+03
H=30m,T=14s	-2.52E+03	2.06E+03	2.57E+03
H=30m,T= 15s	-2.81E+03	2.06E+03	3.72E+03
H=30m,T= 16s	-2.85E+03	2.06E+03	4.74E+03
H=30m,T= 17s	-3.14E+03	2.06E+03	7.97E+03

Table 9-9 Displacement envelope curves for case1-tension 15%MBL –ballasted-seastate case2

SEASTATE	DISPLACEMENT ENVELOPE CURVE					
	X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC
H=30m,T= 13s	-4.64E+00	6.47E+00	-3.18E+00	2.68E+00	-1.59E+01	1.63E+01
H=30m,T=14s	-6.54E+00	8.55E+00	-4.00E+00	3.02E+00	-1.72E+01	1.78E+01
H=30m,T= 15s	-8.18E+00	9.91E+00	-5.11E+00	3.06E+00	-1.75E+01	1.82E+01
H=30m,T= 16s	-9.58E+00	1.12E+01	-5.75E+00	2.05E+00	-1.79E+01	1.82E+01
H=30m,T= 17s	-1.11E+01	1.46E+01	-1.73E+00	3.76E+00	-1.76E+01	2.07E+01

9.4.1.2.3. Mooring line with tension 30%MBL- Regular wave H=15m, T=9-15s

For mooring line with tension 30%MBL, the maximum and minimum effective tension in regulare waves with wave height 15m and periods from 9s to 15s are shown in fgures 9.18 to 9.24.

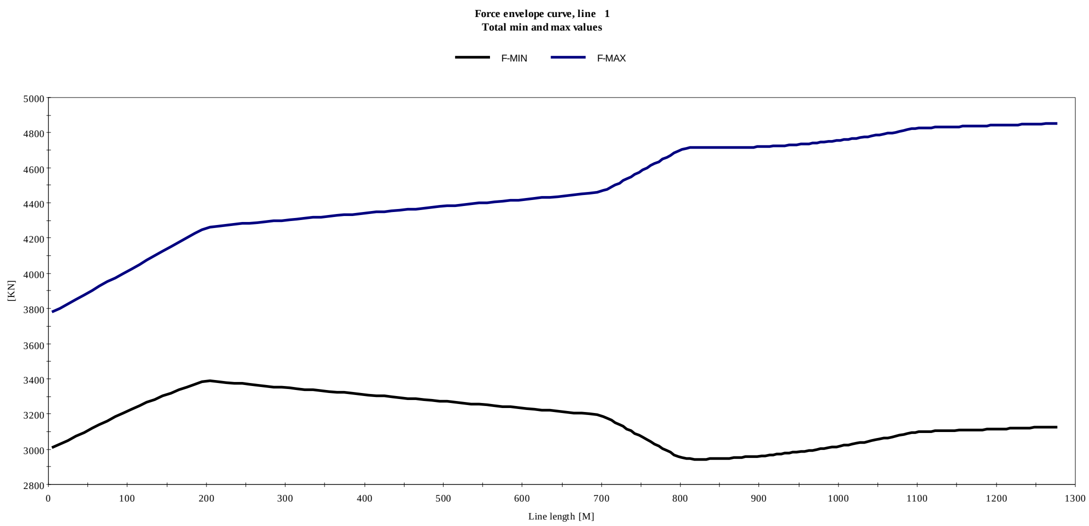

Figure 9.18 Maximum and minimum effective tension in mooring line – case1-tension 30%MBL –ballasted condition - H=15m, Period 9s

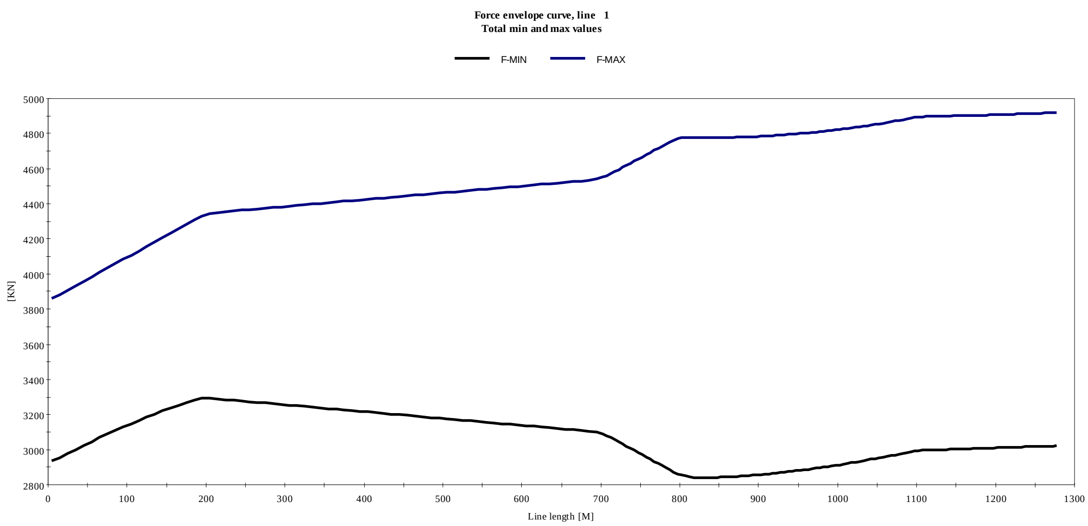

Figure 9.19 Maximum and minimum effective tension in mooring line – case1-tension 30%MBL –ballasted condition - H=15m, Period 10s

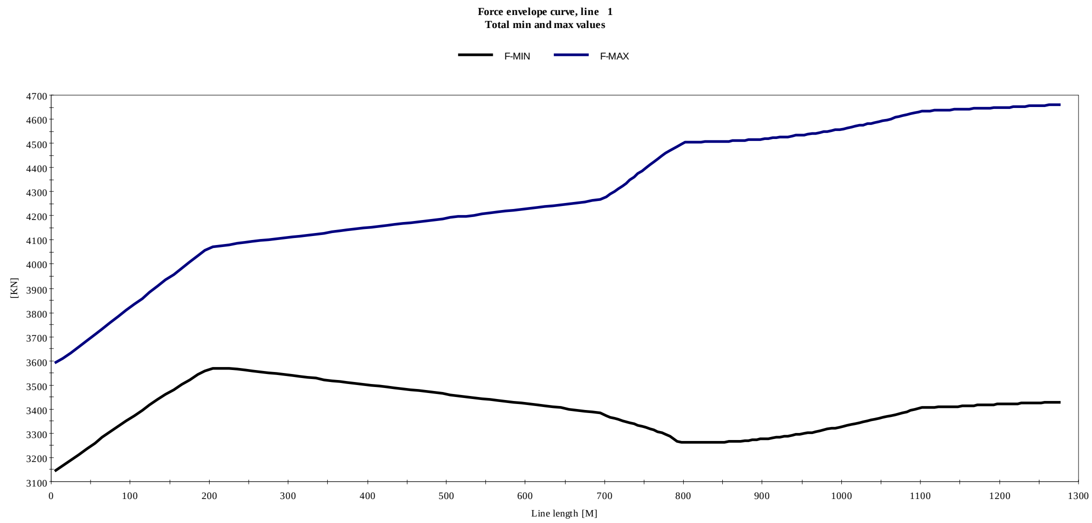

Figure 9.20 Maximum and minimum effective tension in mooring line – case1-tension 30%MBL –ballasted condition - H=15m, Period 11s

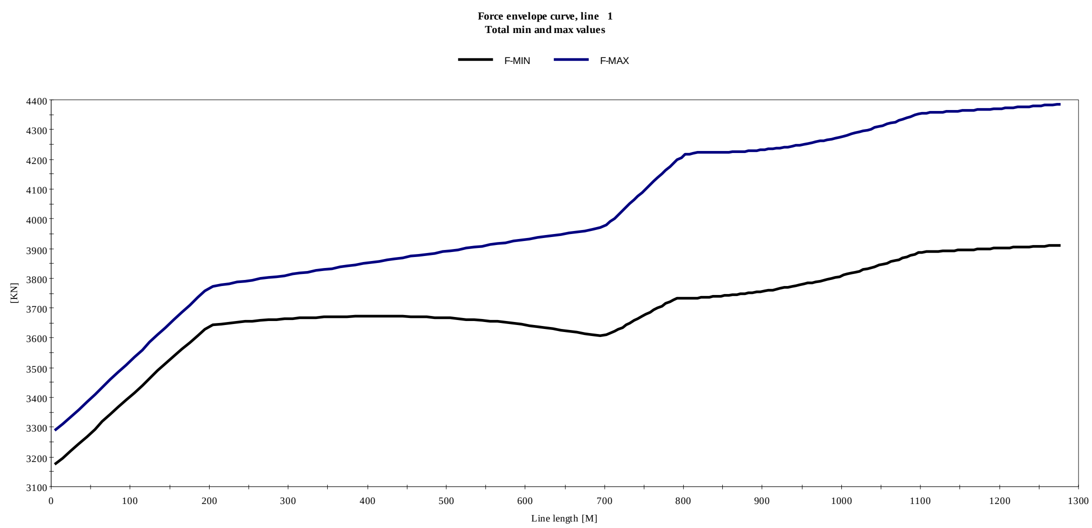

Figure 9.21 Maximum and minimum effective tension in mooring line – case1-tension 30%MBL –ballasted condition - H=15m, Period 12s

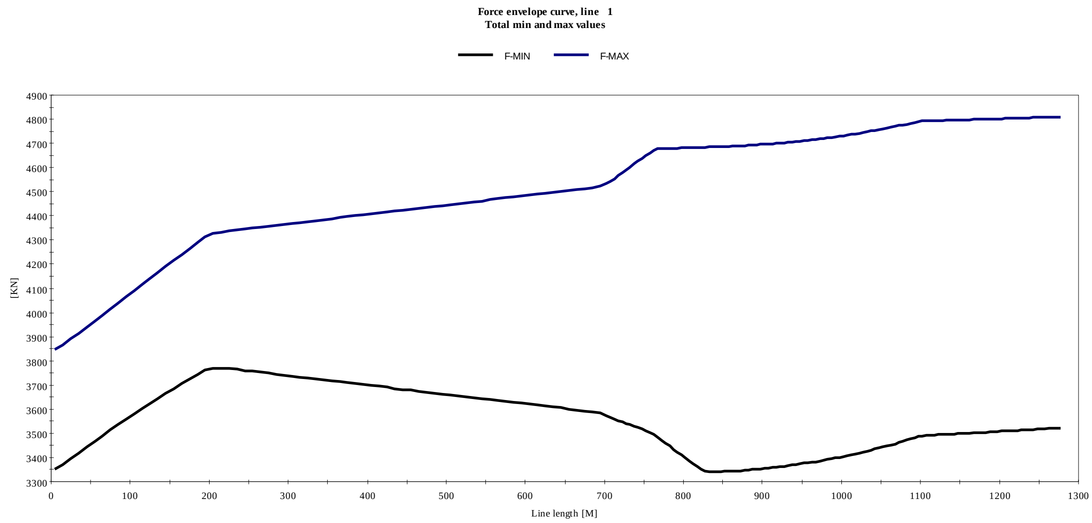

Figure 9.22 Maximum and minimum effective tension in mooring line – case1-tension 30%MBL –ballasted condition - H=15m, Period 13s

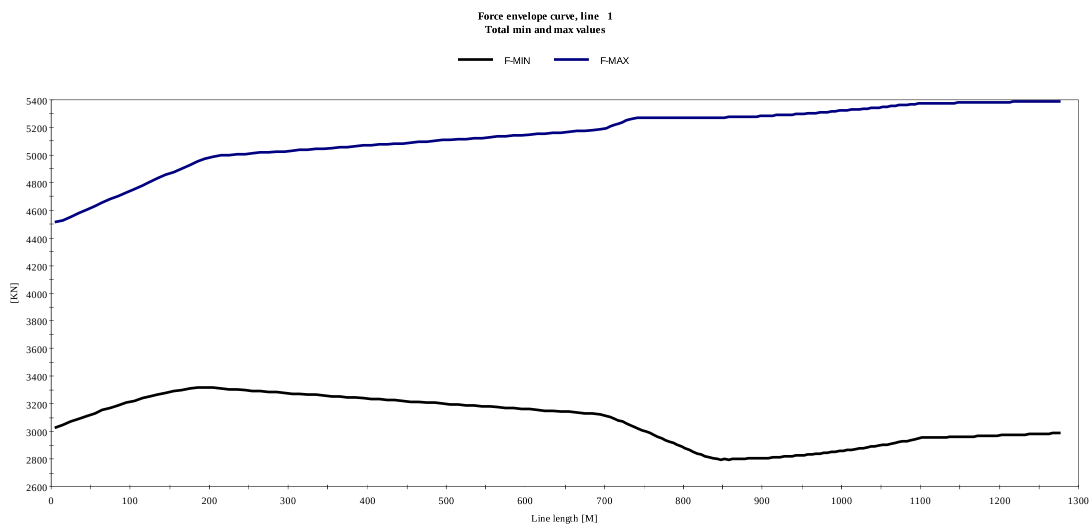

Figure 9.23 Maximum and minimum effective tension in mooring line – case1-tension 30%MBL –ballasted condition - H=15m, Period 14s

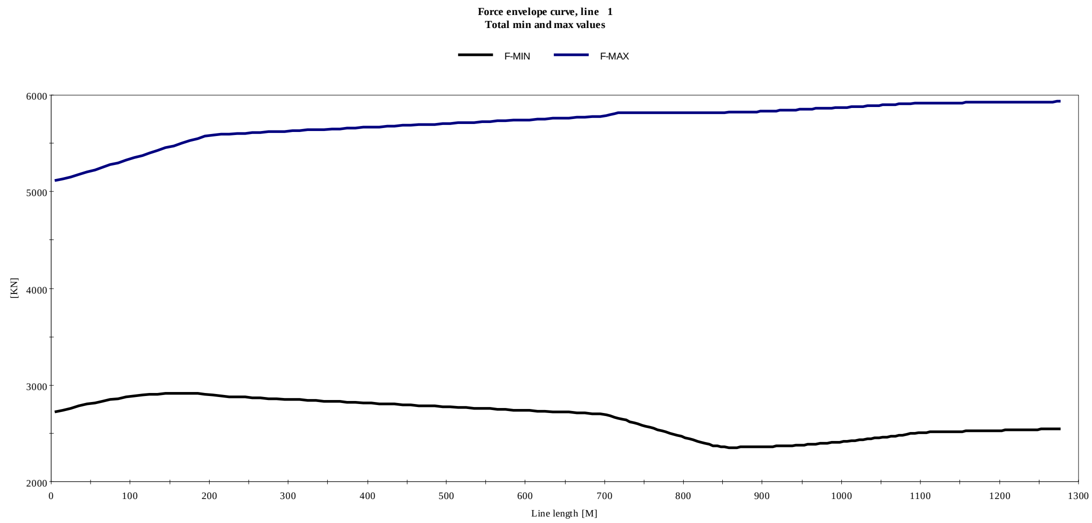

Figure 9.24 Maximum and minimum effective tension in mooring line – case1-tension 30%MBL –ballasted condition - H=15m, Period 15s

The maximum and minimum effective tension in mooring line and the maximum and minimum line displacement in X, Y and Z directions are summarized in tables 9.10 and 9.11.

The following results and behaviours are observed:

- The lowest value for minimum dynamic axial force is obtained in highest seastate with wave height 15m and wave period 15s.
- The highest value for maximum dynamic axial force is obtained in highest seastate with wave height 15m and wave period 15s.
- The lowest value for minimum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 15m and wave period 15s.
- The highest value for maximum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 15m and wave period 15s.

Table 9-10 envelope curves for case1-tension 30%MBL –ballasted-seastate case 1

SEASTATE	FORCE ENVELOPE CURVES		
	AXIAL FORCE		
	MIN DYNAMIC	STATIC FORCE	MAX DYNAMIC
H=15m,T= 9s	-1.03E+03	4.13E+03	7.65E+02
H=15m,T=10s	-1.13E+03	4.13E+03	8.46E+02
H=15m,T= 11s	-7.09E+02	4.13E+03	5.71E+02
H=15m,T= 12s	-2.37E+02	4.13E+03	2.72E+02
H=15m,T= 13s	-6.31E+02	4.13E+03	8.28E+02
H=15m,T= 14s	-1.18E+03	4.13E+03	1.49E+03
H=15m,T=15s	-1.63E+03	4.13E+03	2.09E+03

Table 9-11 Displacement envelope curves for case1-tension 30%MBL –ballasted-seastate case 1

SEASTATE	DISPLACEMENT ENVELOPE CURVE					
	X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC
H=15m,T= 9s	-5.11E-01	7.74E-01	-4.00E-01	3.56E-01	-4.54E+00	3.84E+00
H=15m,T=10s	-5.79E-01	7.94E-01	-6.11E-02	8.51E-02	-5.32E+00	4.67E+00
H=15m,T= 11s	-5.62E-01	6.83E-01	-5.86E-01	5.84E-01	-5.10E+00	5.13E+00
H=15m,T= 12s	-1.48E+00	1.79E+00	-1.10E+00	1.06E+00	-6.74E+00	6.80E+00
H=15m,T= 13s	-2.54E+00	3.00E+00	-1.49E+00	1.37E+00	-8.04E+00	8.14E+00
H=15m,T= 14s	-3.52E+00	4.02E+00	-1.80E+00	1.56E+00	-8.72E+00	8.85E+00
H=15m,T=15s	-4.30E+00	4.74E+00	-2.14E+00	1.62E+00	-8.89E+00	9.06E+00

9.4.1.2.4. Mooring line with tension 30%MBL- Regular wave H=30m, T=13-17s

For mooring line with tension 30%MBL, the maximum and minimum effective tension in regulare waves with wave height 30m and periods from 13s to 17s are shown in fgures 9.25 to 9.29.

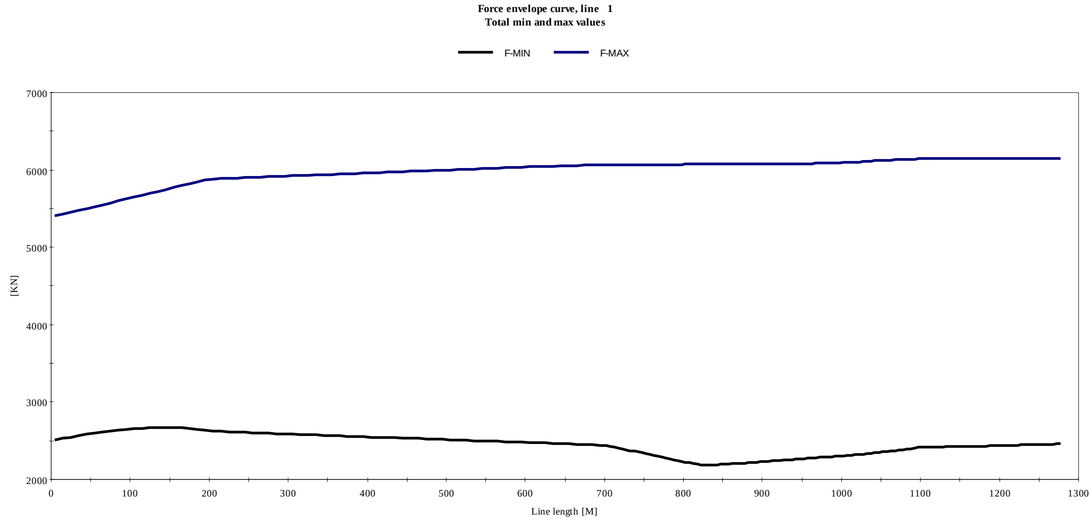

Figure 9.25 Maximum and minimum effective tension in mooring line – case1-tension 30%MBL –ballasted condition - H=30m, Period 13s

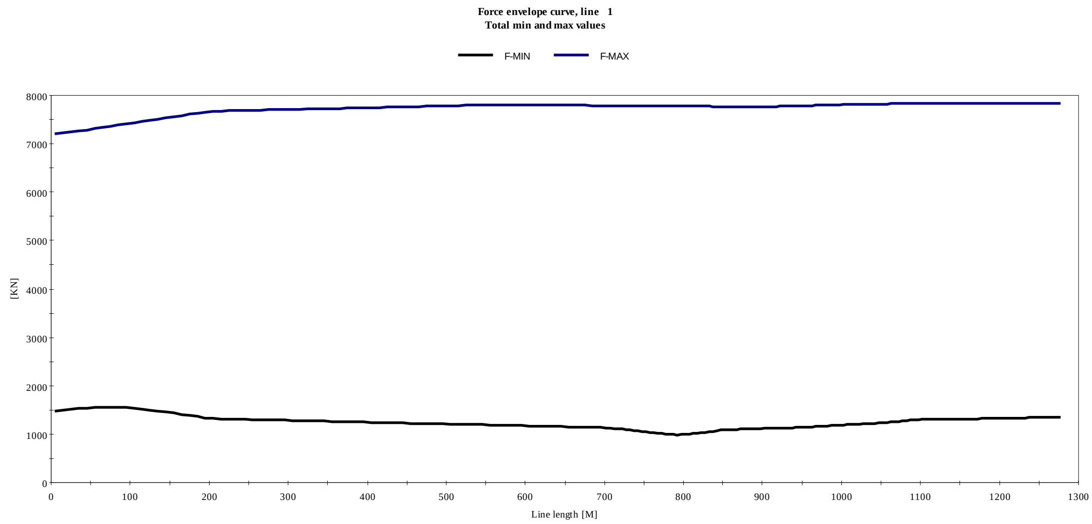

Figure 9.26 Maximum and minimum effective tension in mooring line – case1-tension 30%MBL –ballasted condition - H=30m, Period 14s

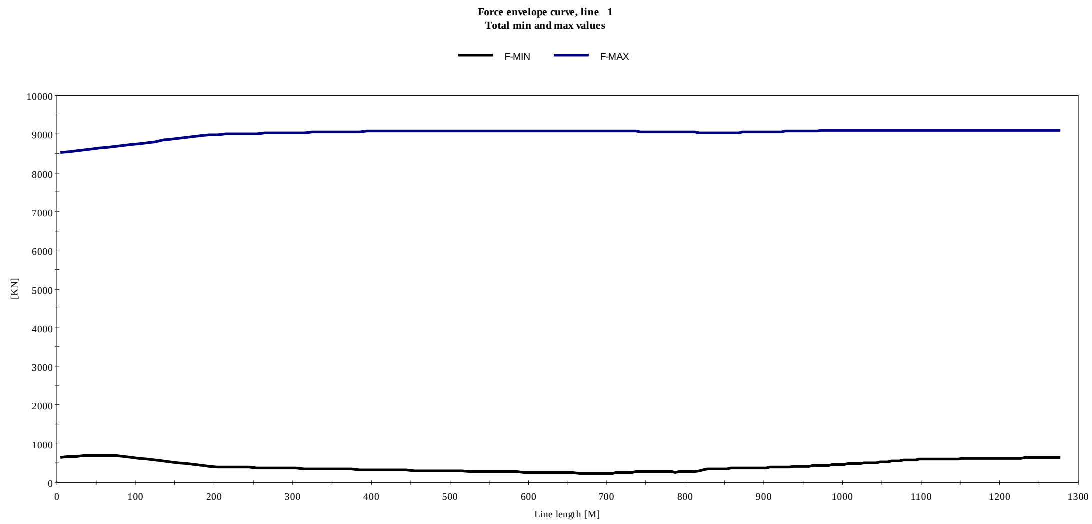

Figure 9.27 Maximum and minimum effective tension in mooring line – case1-tension 30%MBL –ballasted condition - H=30m, Period 15s

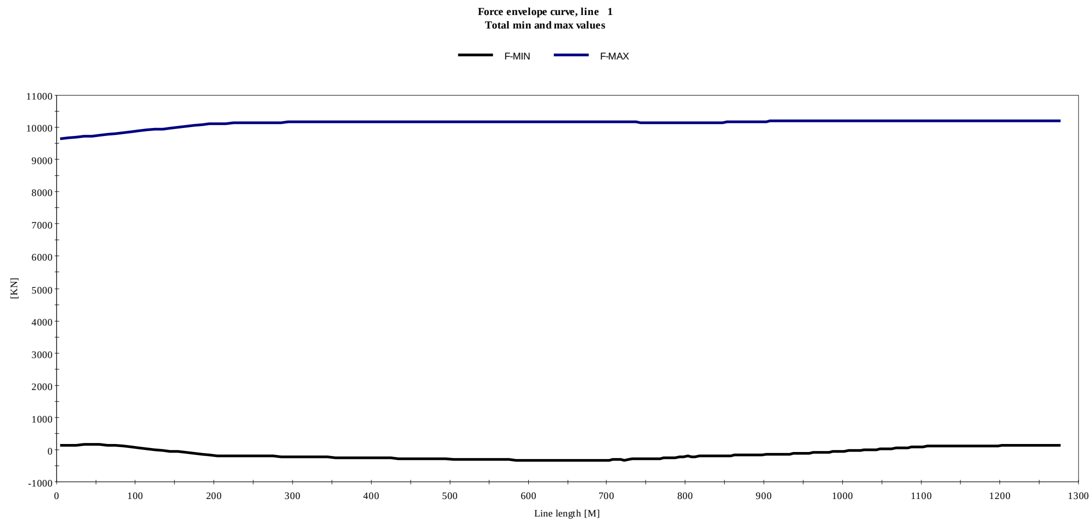

Figure 9.28 Maximum and minimum effective tension in mooring line – case1-tension 30%MBL –ballasted condition - H=30m, Period 16s

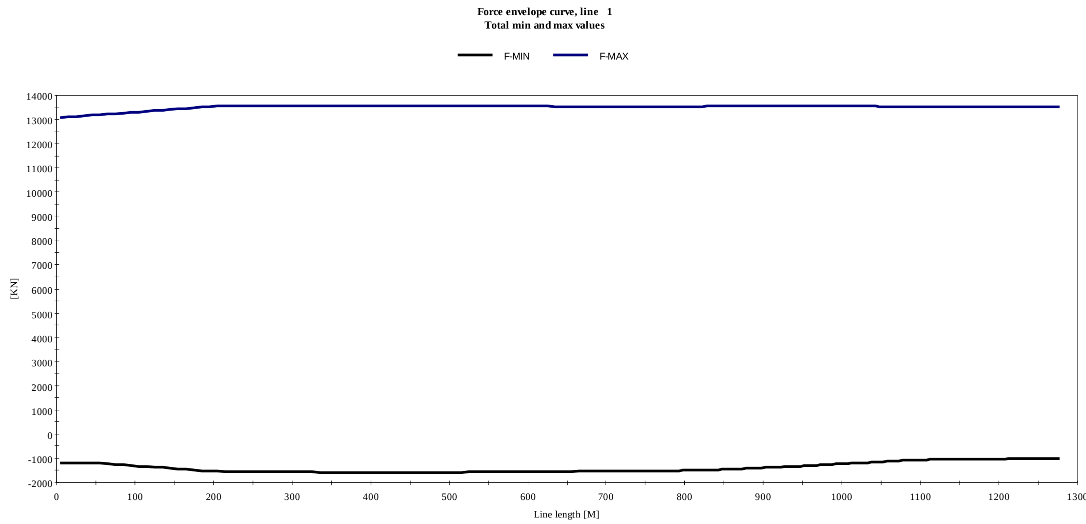

Figure 9.29 Maximum and minimum effective tension in mooring line – case1-tension 30%MBL –ballasted condition - H=30m, Period 17s

The maximum and minimum effective tension in mooring line and the maximum and minimum line displacement in X, Y and Z directions are summarized in tables 9.12 and 9.13.

The following trends and behaviours are extracted:

- The lowest observed value for minimum dynamic axial force is obtained in highest seastate with wave height 30m and wave period 17s.
- The highest value for maximum dynamic axial force is obtained in highest seastate with wave height 30m and wave period 17s.
- The lowest value for minimum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 30m and wave period 17s.
- The highest value for maximum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 30m and wave period 17s.

Table 9-12 Force envelope curves for case1-tension 30%MBL –ballasted-seastate case 2

SEASTATE	FORCE ENVELOPE CURVES		
	AXIAL FORCE		
	MIN DYNAMIC	STATIC FORCE	MAX DYNAMIC
H=30m,T= 13s	-1.79E+03	4.13E+03	2.39E+03
H=30m,T=14s	-2.96E+03	4.13E+03	4.18E+03
H=30m,T= 15s	-3.69E+03	4.13E+03	5.51E+03
H=30m,T= 16s	-4.18E+03	4.13E+03	6.63E+03
H=30m,T= 17s	-5.46E+03	4.13E+03	1.01E+04

Table 9-13 Displacement envelope curves for case1-tension 30%MBL –ballasted-seastate case2

SEASTATE	DISPLACEMENT ENVELOPE CURVE					
	X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC
H=30m,T= 13s	-4.64E+00	6.47E+00	-3.18E+00	2.68E+00	-1.59E+01	1.63E+01
H=30m,T=14s	-6.54E+00	8.55E+00	-4.00E+00	3.02E+00	-1.72E+01	1.78E+01
H=30m,T= 15s	-8.18E+00	9.91E+00	-5.11E+00	3.06E+00	-1.75E+01	1.82E+01
H=30m,T= 16s	-9.58E+00	1.12E+01	-5.75E+00	2.05E+00	-1.79E+01	1.82E+01
H=30m,T= 17s	-1.11E+01	1.46E+01	-1.73E+00	3.76E+00	-1.76E+01	1.84E+01

9.4.1.2.5. Mooring line with tension 45%MBL- Regular wave H=15m, T=9-15s

For mooring line with tension 45%MBL, the maximum and minimum effective tension in regulare waves with wave height 15m and periods from 9s to 15s are shown in fgures 9.30 to 9.36.

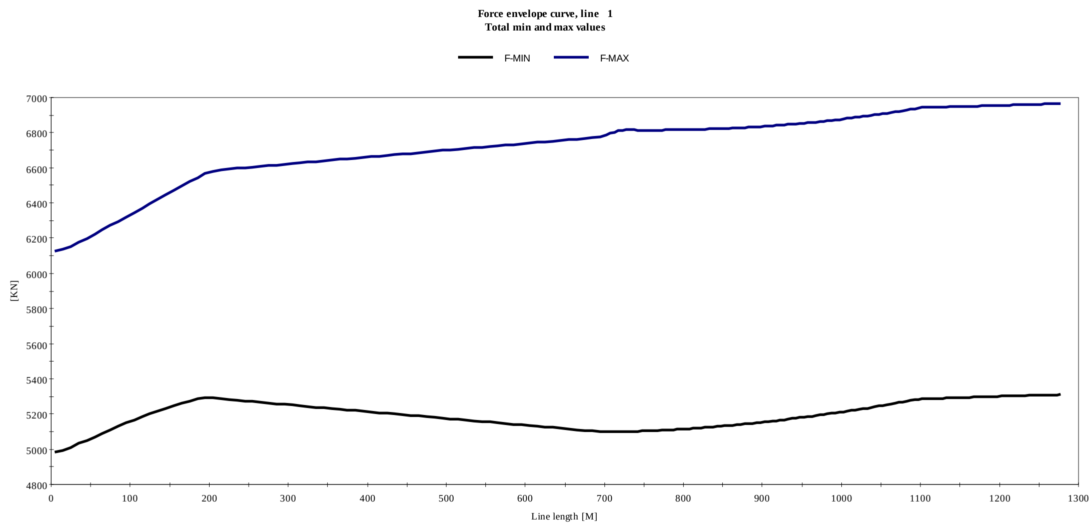

Figure 9.30 Maximum and minimum effective tension in mooring line – case1-tension 45%MBL –ballasted condition - H=15m, Period 9s

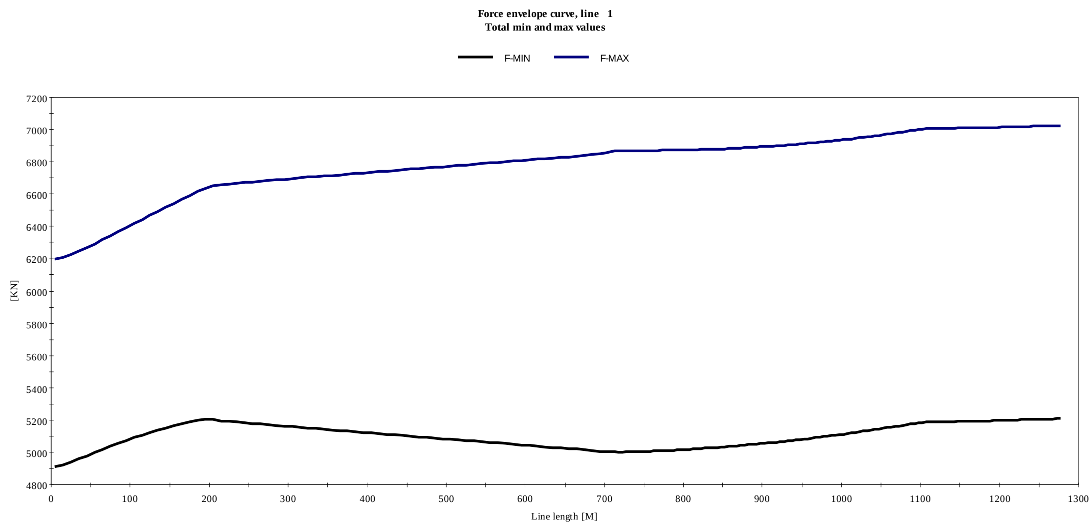

Figure 9.31 Maximum and minimum effective tension in mooring line – case1-tension 45%MBL –ballasted condition - H=15m, Period 10s

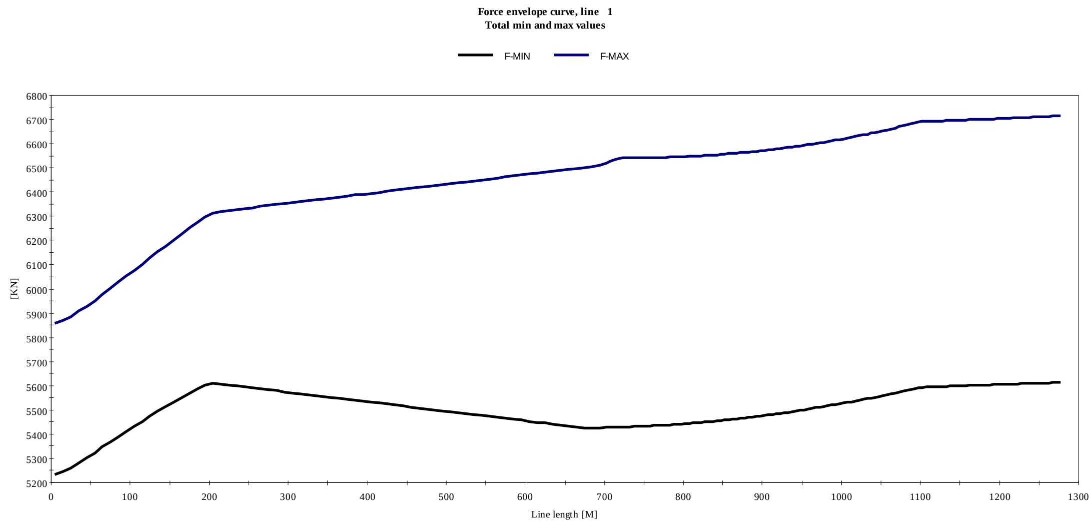

Figure 9.32 Maximum and minimum effective tension in mooring line – case1-tension 45%MBL –ballasted condition - H=15m, Period 11s

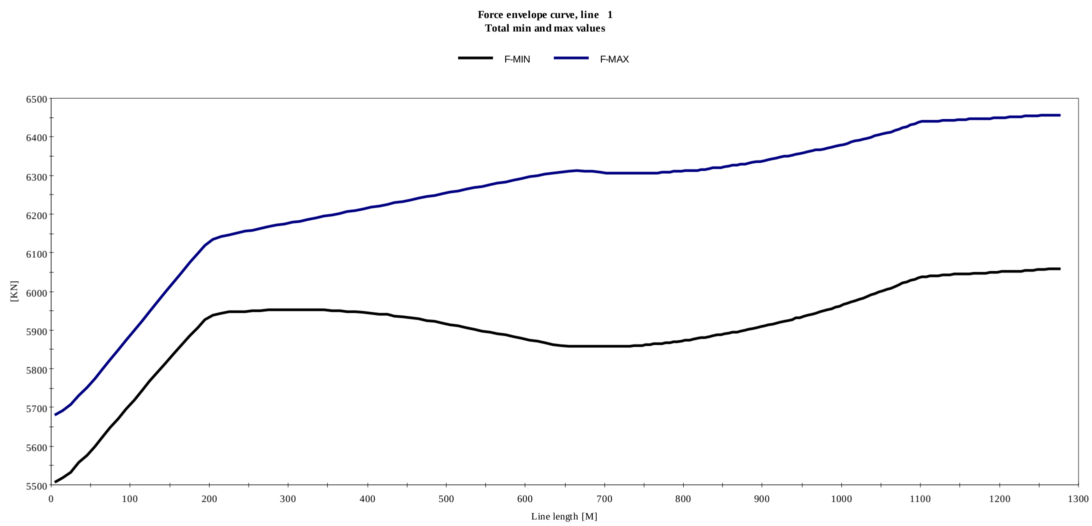

Figure 9.33 Maximum and minimum effective tension in mooring line – case1-tension 45%MBL –ballasted condition - H=15m, Period 12s

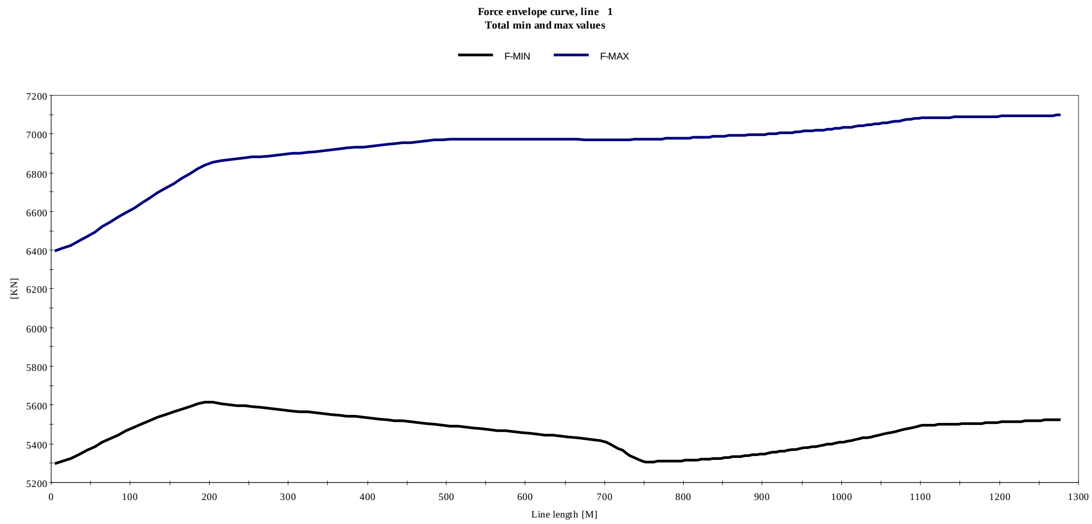

Figure 9.34 Maximum and minimum effective tension in mooring line – case1-tension 45%MBL –ballasted condition - H=15m, Period 13s

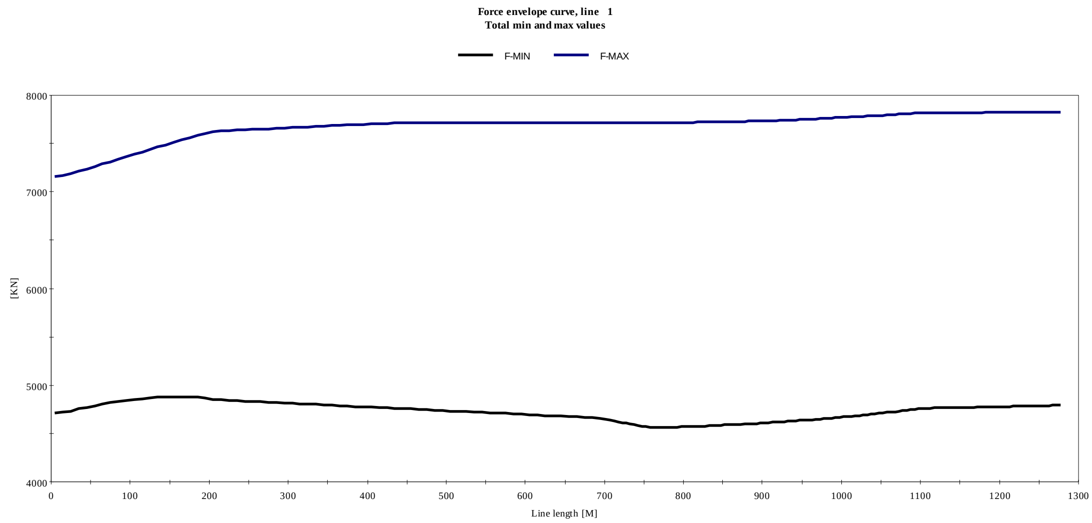

Figure 9.35 Maximum and minimum effective tension in mooring line – case1-tension 45%MBL –ballasted condition - H=15m, Period 14s

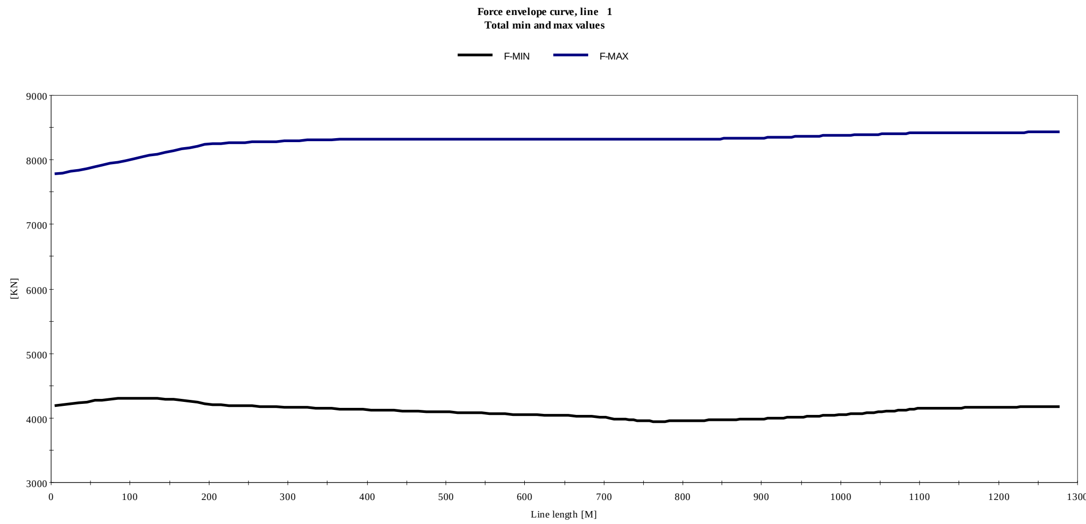

Figure 9.36 Maximum and minimum effective tension in mooring line – case1-tension 45%MBL –ballasted condition - H=15m, Period 15s

The maximum and minimum effective tension in mooring line and the maximum and minimum line displacement in X, Y and Z directions are summarized in tables 9.14 and 9.15.

The following results and behaviours are observed:

- The lowest value for minimum dynamic axial force is obtained in highest seastate with wave height 15m and wave period 15s.
- The highest value for maximum dynamic axial force is obtained in highest seastate with wave height 15m and wave period 15s.
- The lowest value for minimum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 15m and wave period 15s.

The highest value for maximum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 15m and wave period 15s.

Table 9-14 Force envelope curves for case1-tension 45%MBL –ballasted-seastate case 1

SEASTATE	FORCE ENVELOPE CURVES		
	AXIAL FORCE		
	MIN DYNAMIC	STATIC FORCE	MAX DYNAMIC
H=15m,T= 9s	-9.09E+02	6.19E+03	8.06E+02
H=15m,T=10s	-1.01E+03	6.19E+03	8.72E+02
H=15m,T= 11s	-5.80E+02	6.19E+03	5.32E+02
H=15m,T= 12s	-1.51E+02	6.19E+03	3.54E+02
H=15m,T= 13s	-7.04E+02	6.19E+03	1.08E+03
H=15m,T= 14s	-1.45E+03	6.19E+03	1.84E+03
H=15m,T=15s	-2.07E+03	6.19E+03	2.47E+03

Table 9-15 Displacement envelope curves for case1-tension 45%MBL –ballasted-seastate case 1

SEASTATE	DISPLACEMENT ENVELOPE CURVE					
	X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC
H=15m,T= 9s	-5.67E-01	6.52E-01	-4.00E-01	3.56E-01	-3.60E+00	3.60E+00
H=15m,T=10s	-6.14E-01	6.66E-01	-6.11E-02	8.51E-02	-4.31E+00	4.35E+00
H=15m,T= 11s	-5.62E-01	6.83E-01	-5.86E-01	5.84E-01	-5.10E+00	5.13E+00
H=15m,T= 12s	-1.48E+00	1.79E+00	-1.10E+00	1.06E+00	-6.74E+00	6.80E+00
H=15m,T= 13s	-2.54E+00	3.00E+00	-1.49E+00	1.37E+00	-8.04E+00	8.14E+00
H=15m,T= 14s	-3.52E+00	4.02E+00	-1.80E+00	1.56E+00	-8.72E+00	8.85E+00
H=15m,T=15s	-4.30E+00	4.74E+00	-2.14E+00	1.62E+00	-8.89E+00	9.06E+00

9.4.1.2.6. Mooring line with tension 45%MBL- Regular wave H=30m, T=13-17s

For mooring line with tension 45%MBL, the maximum and minimum effective tension in regulare waves with wave height 30m and periods from 13s to 17s are shown in fgures 9.37 to 9.41.

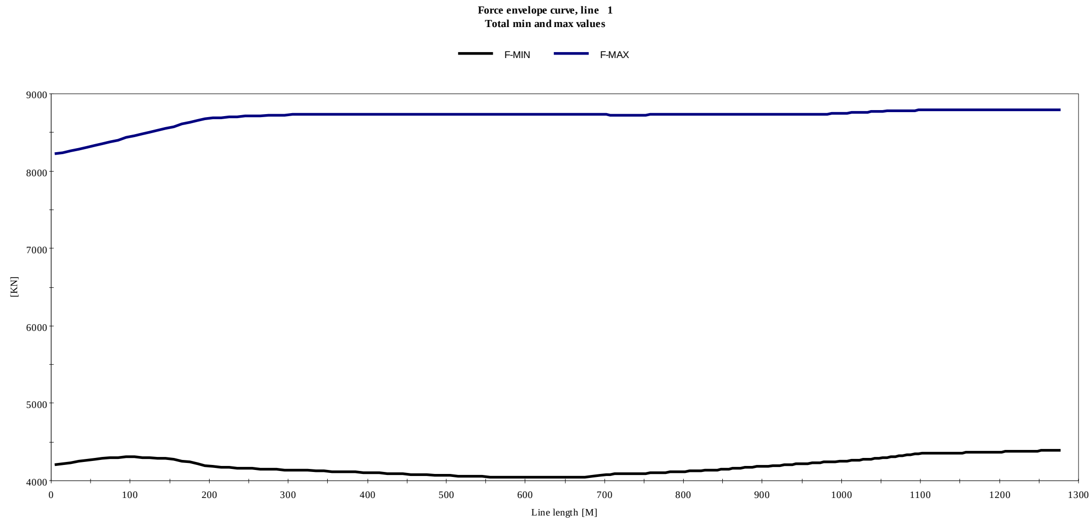

Figure 9.37 Maximum and minimum effective tension in mooring line – case1-tension 45%MBL –ballasted condition - H=30m, Period 13s

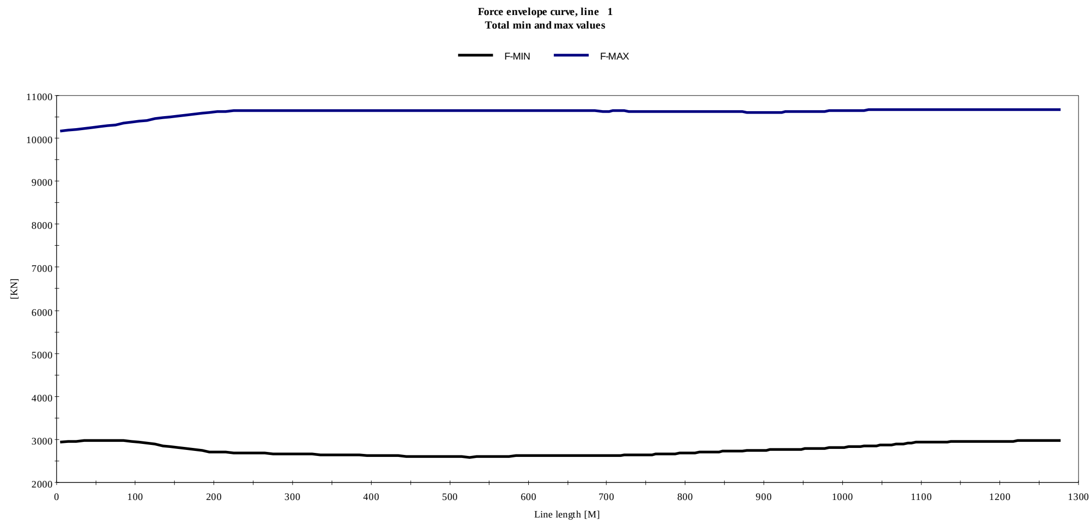

Figure 9.38 Maximum and minimum effective tension in mooring line – case1-tension 45%MBL –ballasted condition - H=30m, Period 14s

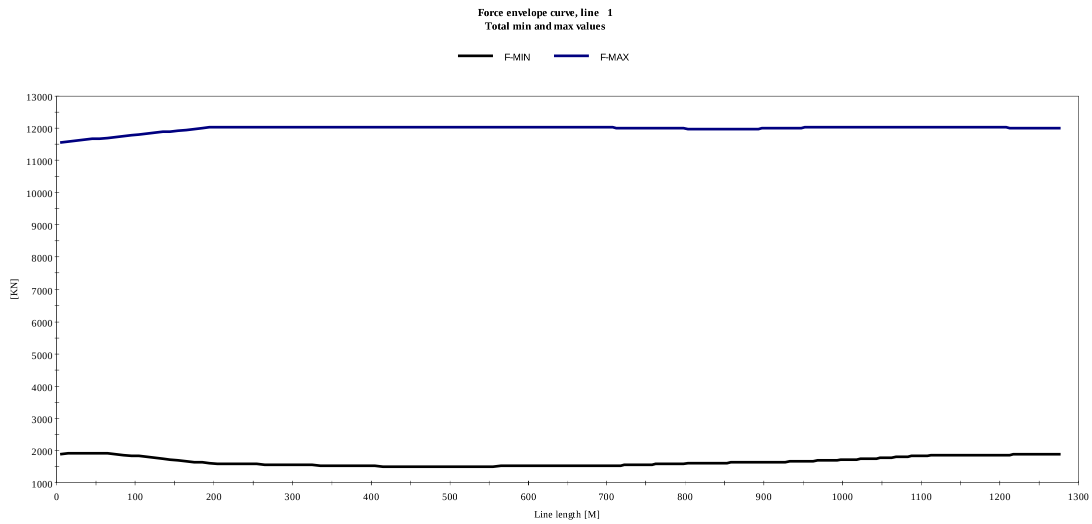

Figure 9.39 Maximum and minimum effective tension in mooring line – case1-tension 45%MBL –ballasted condition - H=30m, Period 15s

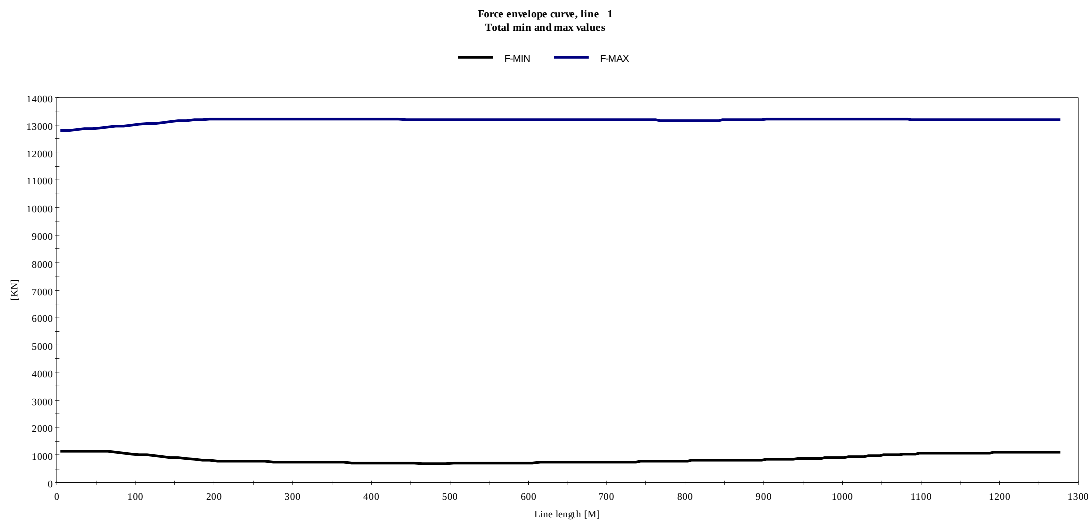

Figure 9.40 Maximum and minimum effective tension in mooring line – case1-tension 45%MBL –ballasted condition - H=30m, Period 16s

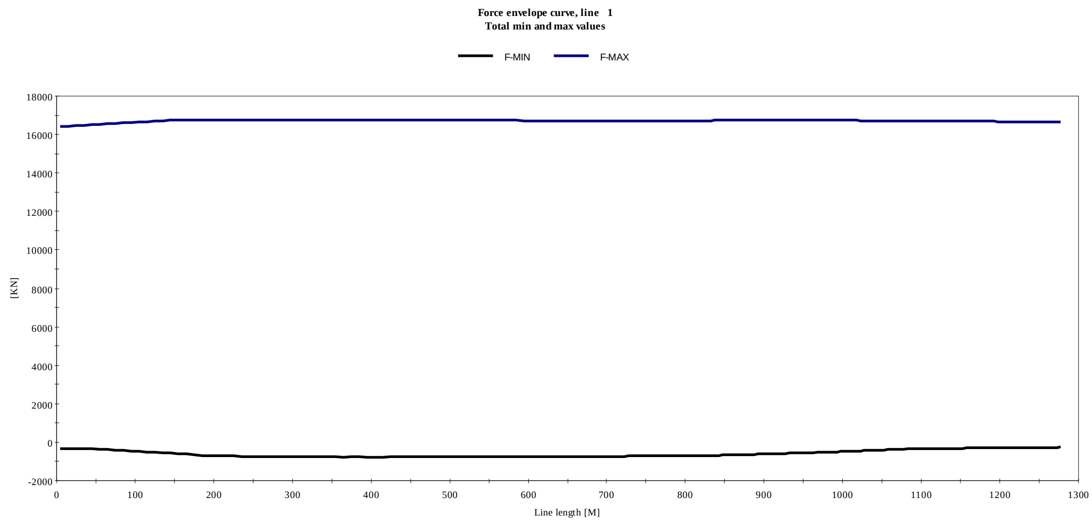

Figure 9.41 Maximum and minimum effective tension in mooring line – case1-tension 45%MBL –ballasted condition - H=30m, Period 17s

The maximum and minimum effective tension in mooring line and the maximum and minimum line displacement in X, Y and Z directions are summarized in tables 9.16 and 9.17.

The following trends and behaviours are extracted:

- The lowest observed value for minimum dynamic axial force is obtained in highest seastate with wave height 30m and wave period 17s.
- The highest value for maximum dynamic axial force is obtained in highest seastate with wave height 30m and wave period 17s.
- The lowest value for minimum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 30m and wave period 17s.
- The highest value for maximum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 30m and wave period 17s.

Table 9-16 Force envelope curves for case1-tension 45%MBL –ballasted-seastate case 2

SEASTATE	FORCE ENVELOPE CURVES		
	AXIAL FORCE		
	MIN DYNAMIC	STATIC FORCE	MAX DYNAMIC
H=30m,T= 13s	-1.92E+03	6.19E+03	2.91E+03
H=30m,T=14s	-3.38E+03	6.19E+03	4.85E+03
H=30m,T= 15s	-4.47E+03	6.19E+03	6.26E+03
H=30m,T= 16s	-5.26E+03	6.19E+03	7.48E+03
H=30m,T= 17s	-6.74E+03	6.19E+03	1.11E+04

Table 9-17 Displacement envelope curves for case1-tension 45%MBL –ballasted-seastate case2

SEASTATE	DISPLACEMENT ENVELOPE CURVE					
	X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC
H=30m,T= 13s	-4.64E+00	6.47E+00	-3.18E+00	2.68E+00	-1.59E+01	1.63E+01
H=30m,T=14s	-6.54E+00	8.55E+00	-4.00E+00	3.02E+00	-1.72E+01	1.78E+01
H=30m,T= 15s	-8.18E+00	9.91E+00	-5.11E+00	3.06E+00	-1.75E+01	1.82E+01
H=30m,T= 16s	-9.58E+00	1.12E+01	-5.75E+00	2.05E+00	-1.79E+01	1.82E+01
H=30m,T= 17s	-1.11E+01	1.46E+01	-1.73E+00	3.76E+00	-1.76E+01	1.85E+01

9.4.2. Case 1- loaded condition

9.4.2.1. Static analysis

Static analysis was carried out for mooring line when the tension on line is 15%, 30% and 45% of MBL (minimum breaking load), two sets of regular waves with different wave period and wave heights applied on system and vessel is in loaded condition. Mooring line shapes in XZ plane are shown in figures 9.42, 9.43, 9.44. With comparison between these figures, when the tension on the mooring line increased the seafloor interaction will decreased.

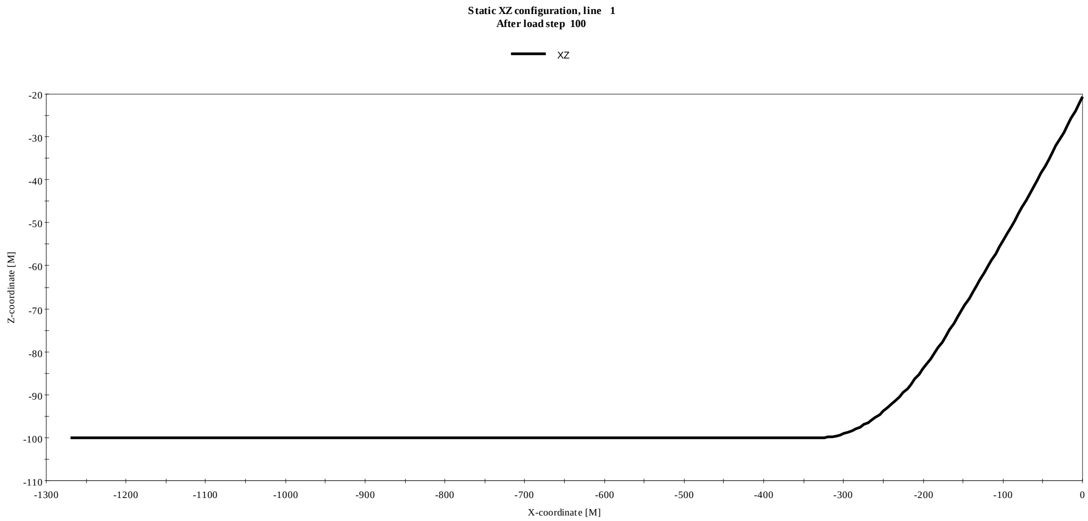

Figure 9.42 Mooring line shape in XZ plane with tension 15% MBL-case1- loaded

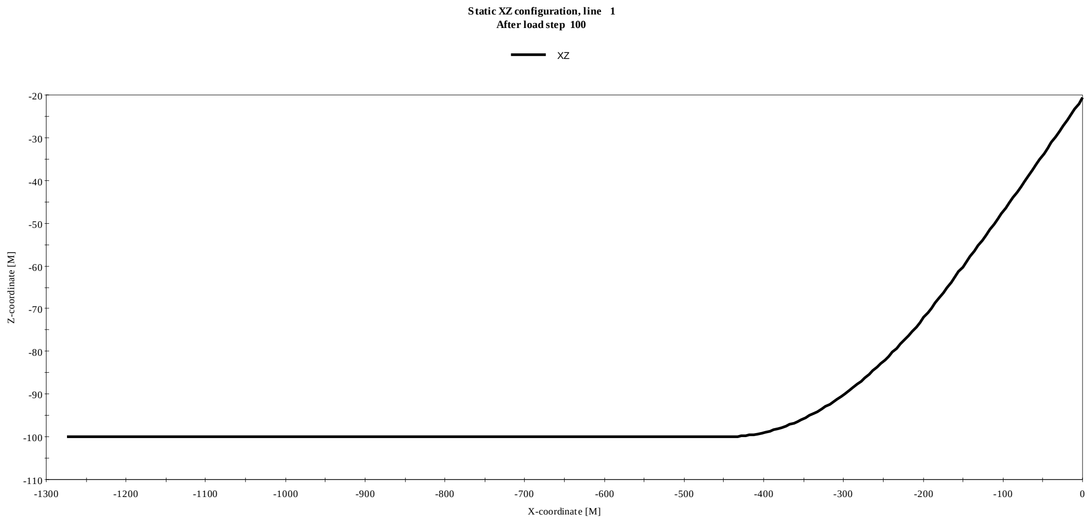

Figure 9.43 Mooring line shape in XZ plane with tension 30% MBL-case1-loaded

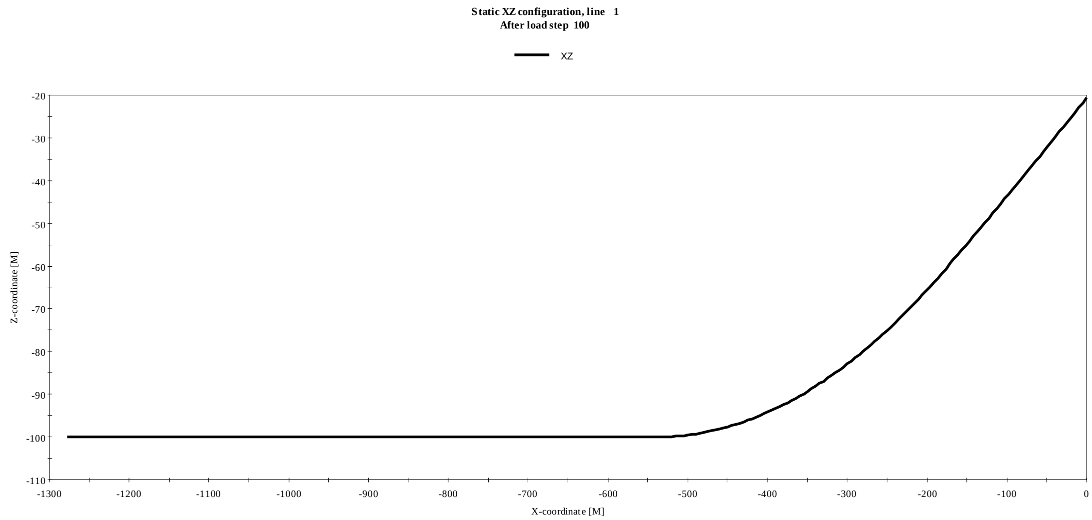

Figure 9.44 Mooring line shape in XZ plane with tension 45% MBL-case1-loaded

9.4.2.2. Dynamic analysis

The maximum and minimum effective tension of the mooring line for three line configuration when the tension applied on line is 15%, 30% and 45% are shown below. Also, in this section all line displacements are summerized in following tables.

9.4.2.2.1. Mooring line with tension 15%MBL- Regular wave H=15m, T=9-15

For mooring line with tension 15%MBL, the maximum and minimum effective tension in regulare waves with wave height 15m and periods from 9s to 15s are shown in fgures 9.45 to 9.51.

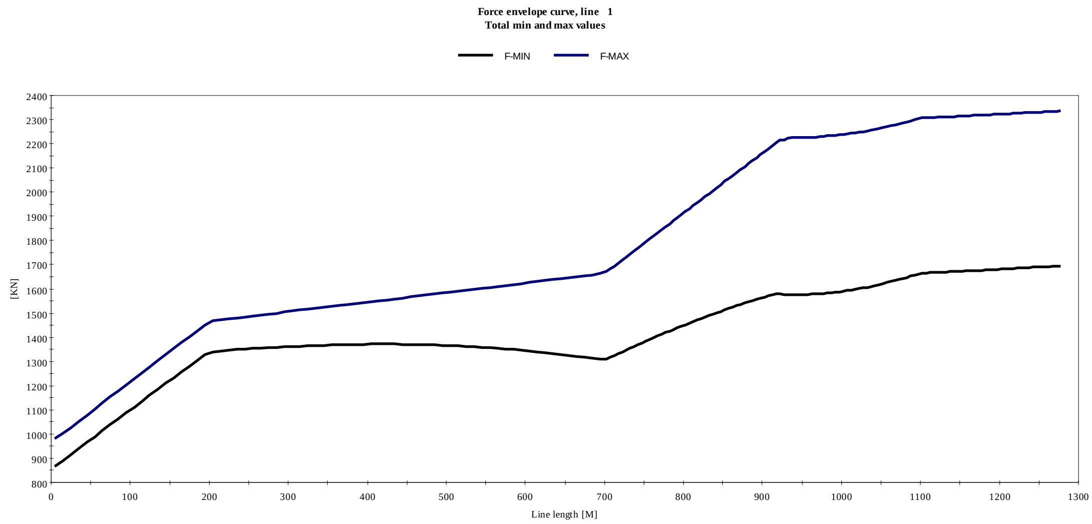

Figure 9.45 Maximum and minimum effective tension in mooring line – case1-tension 15%MBL –loaded condition - H=15m, Period 9s

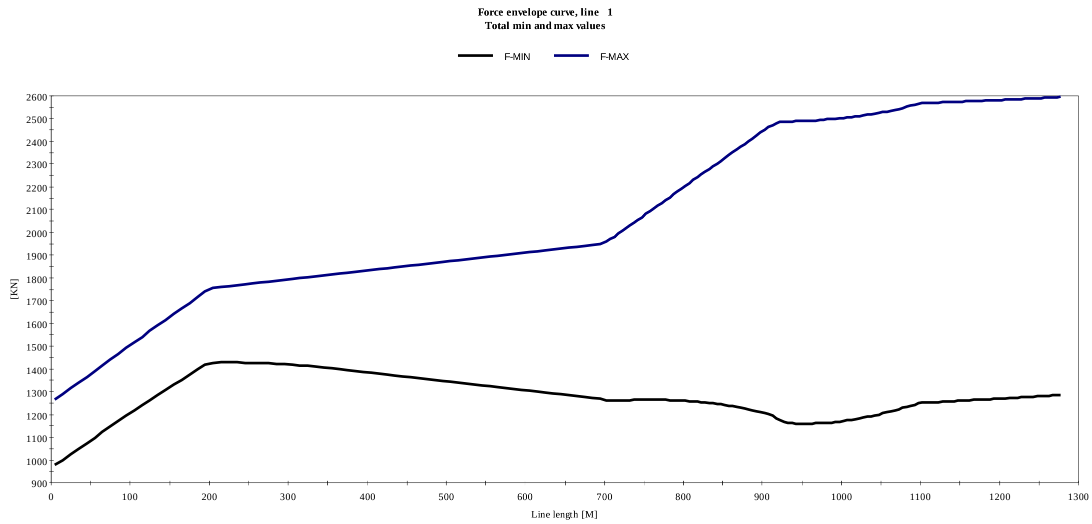

Figure 9.46 Maximum and minimum effective tension in mooring line – case1-tension 15%MBL –loaded condition - H=15m, Period 10s

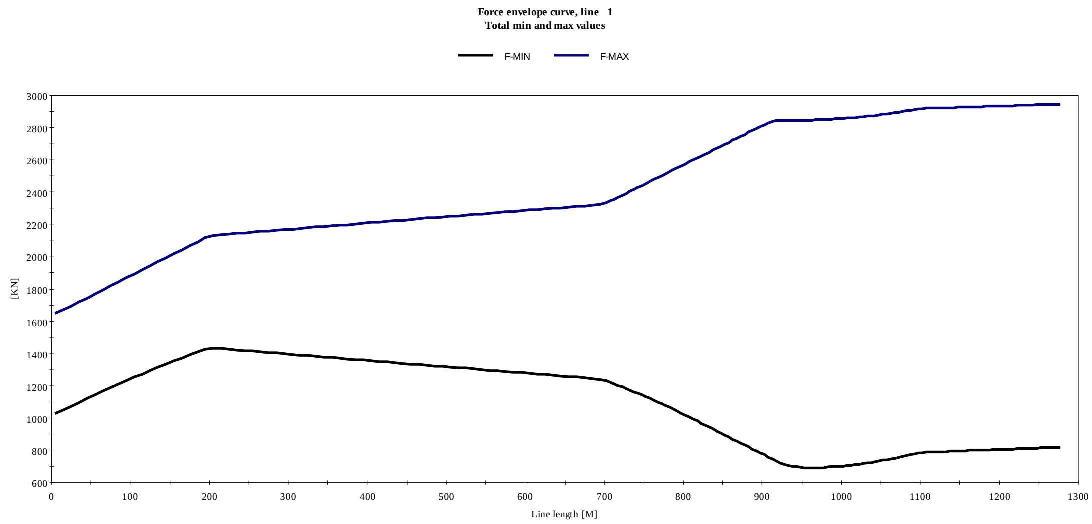

Figure 9.47 Maximum and minimum effective tension in mooring line – case1-tension 15%MBL –loaded condition - H=15m, Period 11s

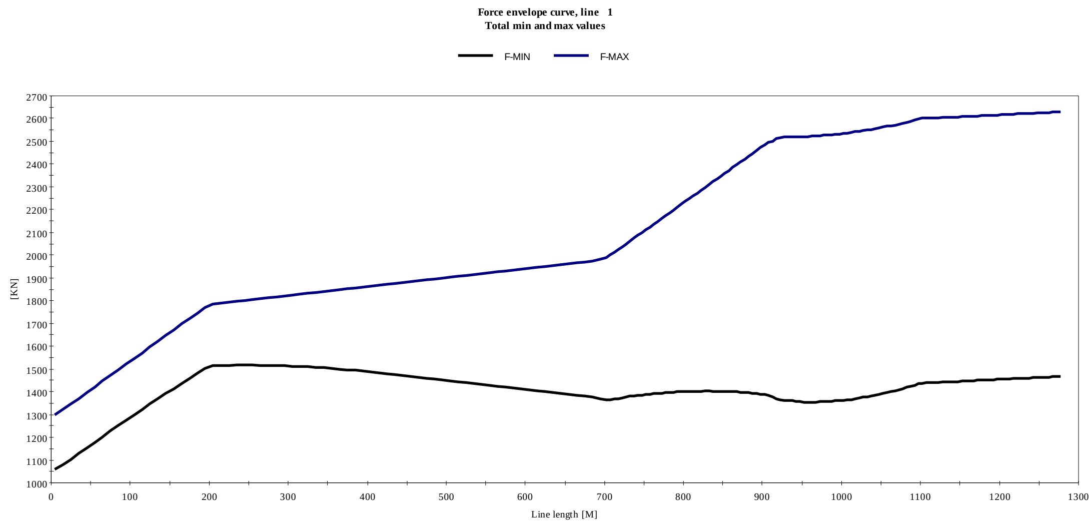

Figure 9.48 Maximum and minimum effective tension in mooring line – case1-tension 15%MBL –loaded condition - H=15m, Period 12s

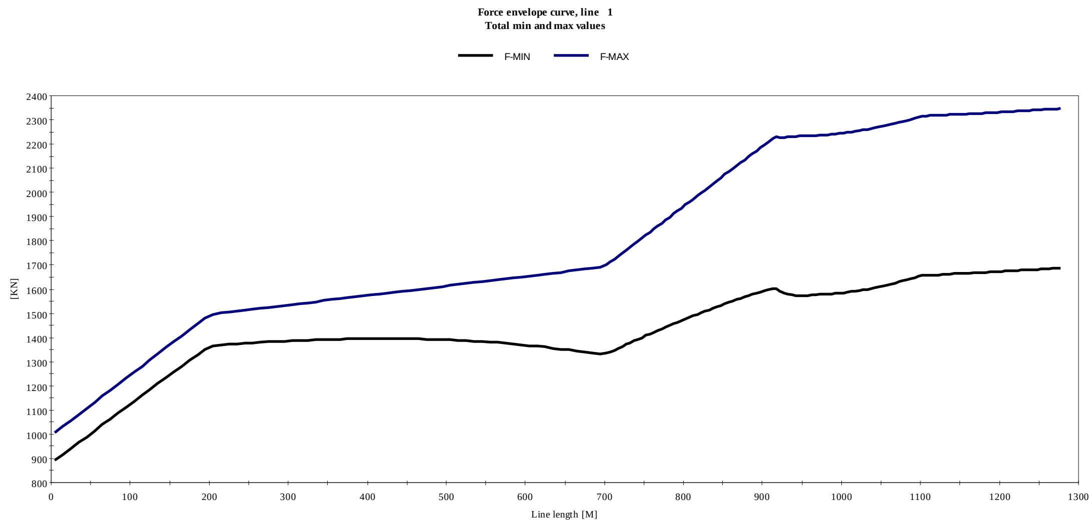

Figure 9.49 Maximum and minimum effective tension in mooring line – case1-tension 15%MBL –loaded condition - H=15m, Period 13s

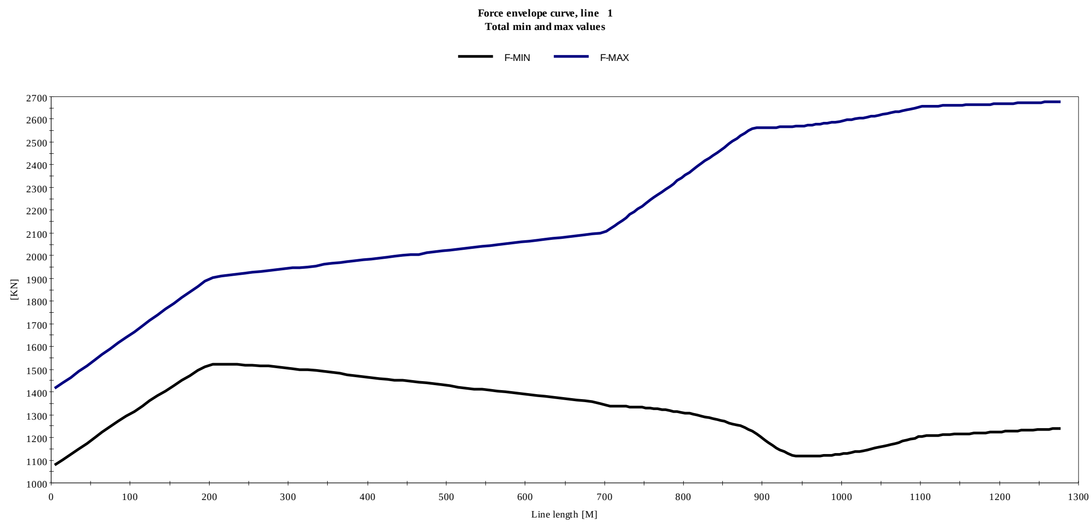

Figure 9.50 Maximum and minimum effective tension in mooring line – case1-tension 15%MBL –loaded condition - H=15m, Period 14s

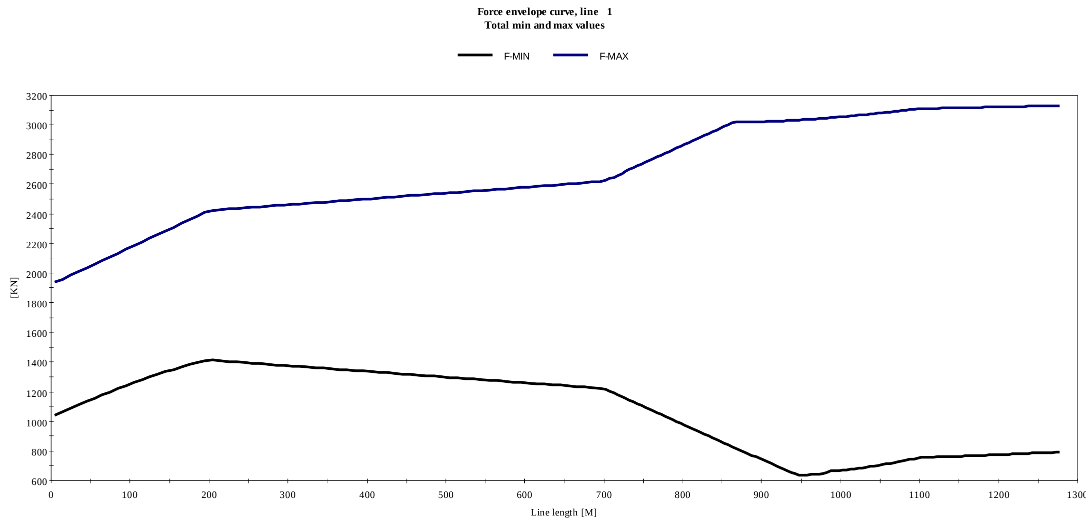

Figure 9.51 Maximum and minimum effective tension in mooring line – case1-tension 15%MBL –loaded condition - H=15m, Period 15s

The maximum and minimum effective tension in mooring line and the maximum and minimum line displacement in X, Y and Z directions are summarized in tables 9.18 and 9.19.

The following results and behaviours are observed:

- The lowest value for minimum dynamic axial force is obtained in highest seastate with wave height 15m and wave period 15s.
- The highest value for maximum dynamic axial force is obtained in highest seastate with wave height 15m and wave period 15s.
- The lowest value for minimum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 15m and wave period 15s.
- The highest value for maximum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 15m and wave period 15s.

Table 9-18 Force envelope curves for case1-tension 15%MBL –loaded -seastate case 1

SEASTATE	FORCE ENVELOPE CURVES		
	AXIAL FORCE		
	MIN DYNAMIC	STATIC FORCE	MAX DYNAMIC
H=15m,T= 9s	-3.78E+02	2.07E+03	3.08E+02
H=15m,T=10s	-7.97E+02	2.07E+03	5.96E+02
H=15m,T= 11s	-1.27E+03	2.07E+03	9.74E+02
H=15m,T= 12s	-6.05E+02	2.07E+03	6.27E+02
H=15m,T= 13s	-3.83E+02	2.07E+03	3.37E+02
H=15m,T= 14s	-8.40E+02	2.07E+03	7.46E+02
H=15m,T=15s	-1.32E+03	2.07E+03	1.27E+03

Table 9-19 Displacement envelope curves for case1-tension 15%MBL –loaded -seastate case 1

SEASTATE	DISPLACEMENT ENVELOPE CURVE					
	X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC
H=15m,T= 9s	-3.01E-01	5.27E-01	-6.09E-01	5.55E-01	-3.52E+00	2.91E+00
H=15m,T=10s	-6.23E-01	7.52E-01	-3.15E-01	3.13E-01	-5.50E+00	4.16E+00
H=15m,T= 11s	-7.71E-01	1.16E+00	-5.52E-01	5.50E-01	-7.49E+00	6.19E+00
H=15m,T= 12s	-1.05E+00	1.28E+00	-1.11E+00	1.08E+00	-6.94E+00	7.00E+00
H=15m,T= 13s	-2.08E+00	2.45E+00	-1.54E+00	1.49E+00	-7.75E+00	7.84E+00
H=15m,T= 14s	-3.08E+00	3.53E+00	-1.85E+00	1.78E+00	-8.36E+00	8.47E+00
H=15m,T=15s	-3.95E+00	4.43E+00	-2.05E+00	1.95E+00	-9.25E+00	8.81E+00

9.4.2.2.2. Mooring line with tension 15%MBL- Regular wave H=30m, T=13-17s

For mooring line with tension 15%MBL, the maximum and minimum effective tension in regulare waves with wave height 30m and periods from 13s to 17s are shown in fgures 9.52 to 9.56.

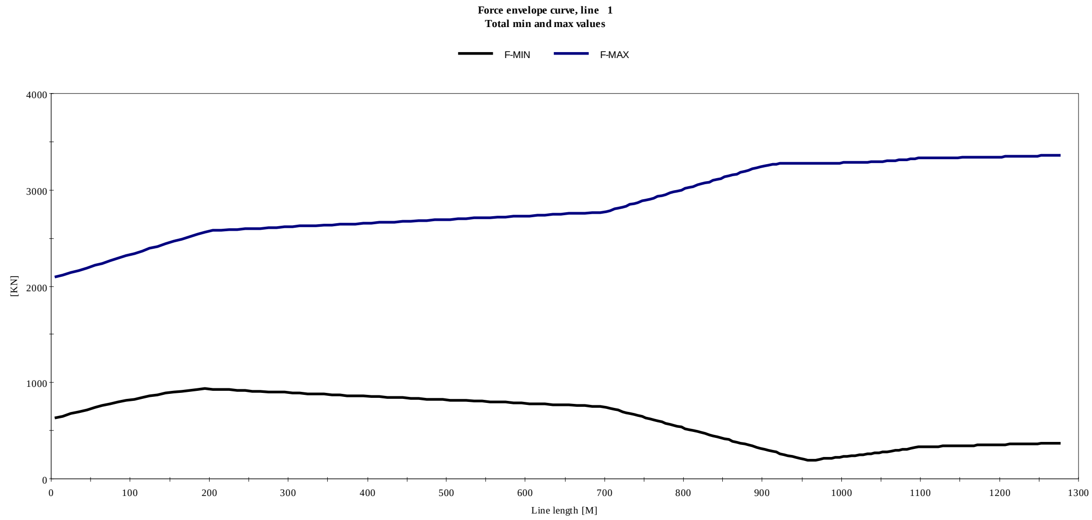

Figure 9.52 Maximum and minimum effective tension in mooring line – case1-tension 15%MBL –loaded condition - H=30m, Period 13s

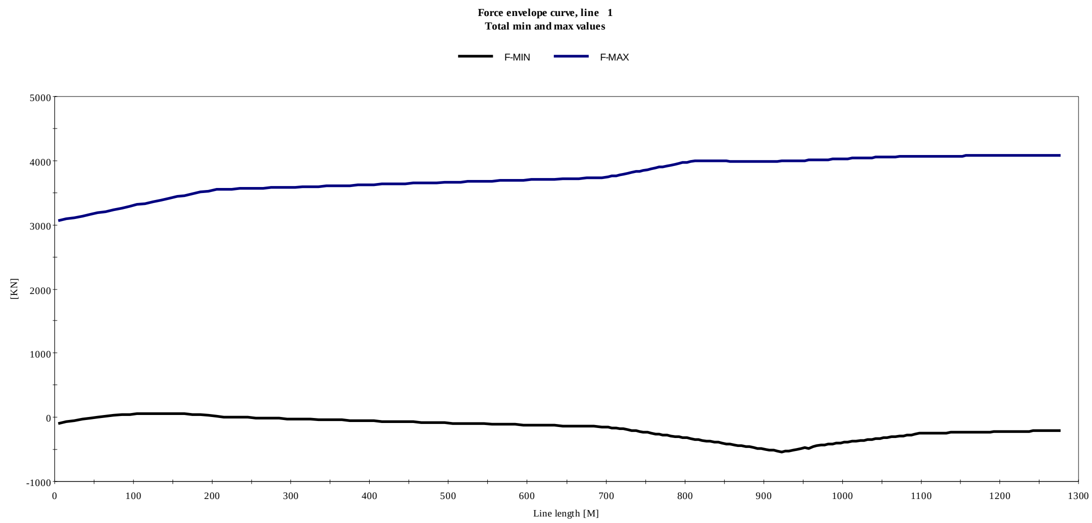

Figure 9.53 Maximum and minimum effective tension in mooring line – case1-tension 15%MBL –loaded condition - H=30m, Period 14s

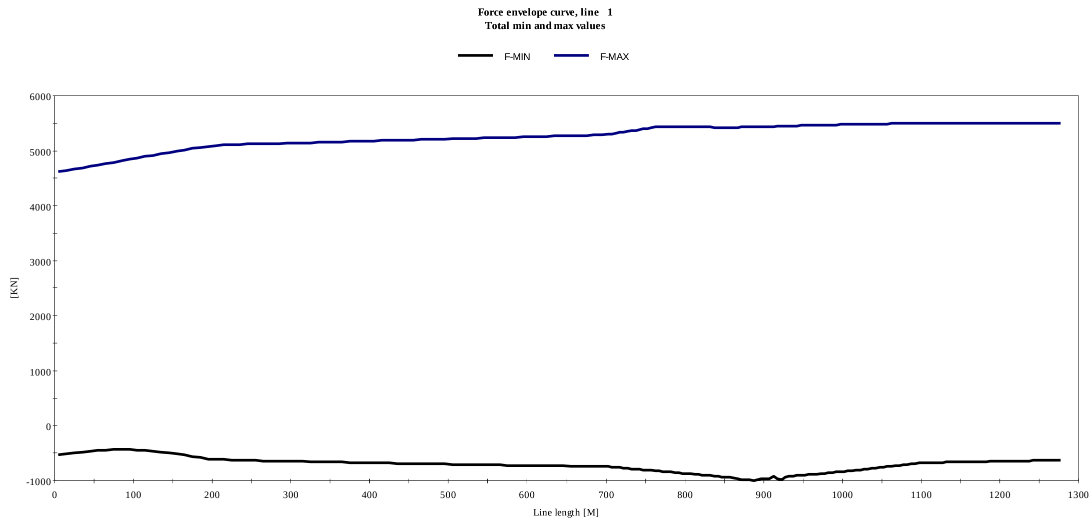

Figure 9.54 Maximum and minimum effective tension in mooring line – case1-tension 15%MBL –loaded condition - H=30m, Period 15s

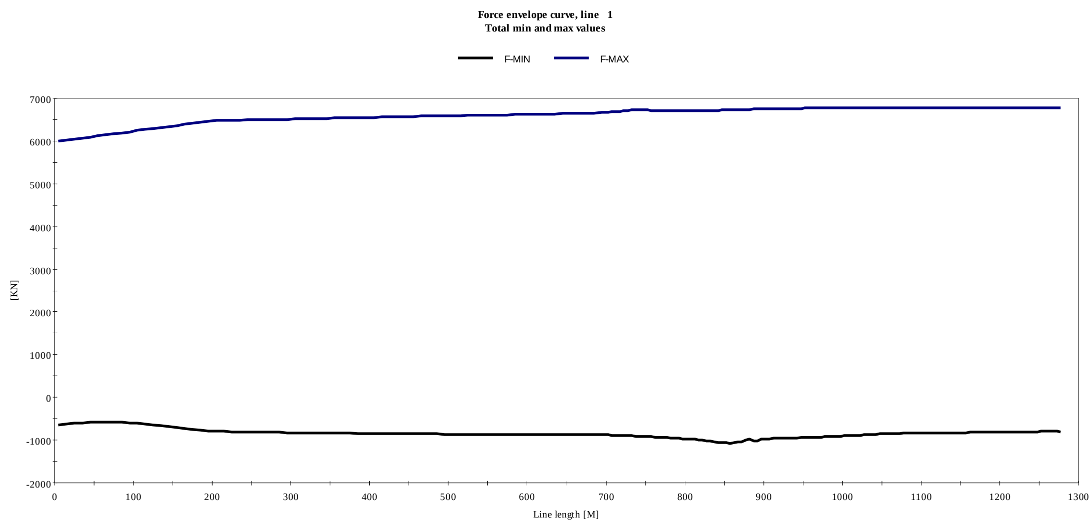

Figure 9.55 Maximum and minimum effective tension in mooring line – case1-tension 15%MBL –loaded condition - H=30m, Period 16s

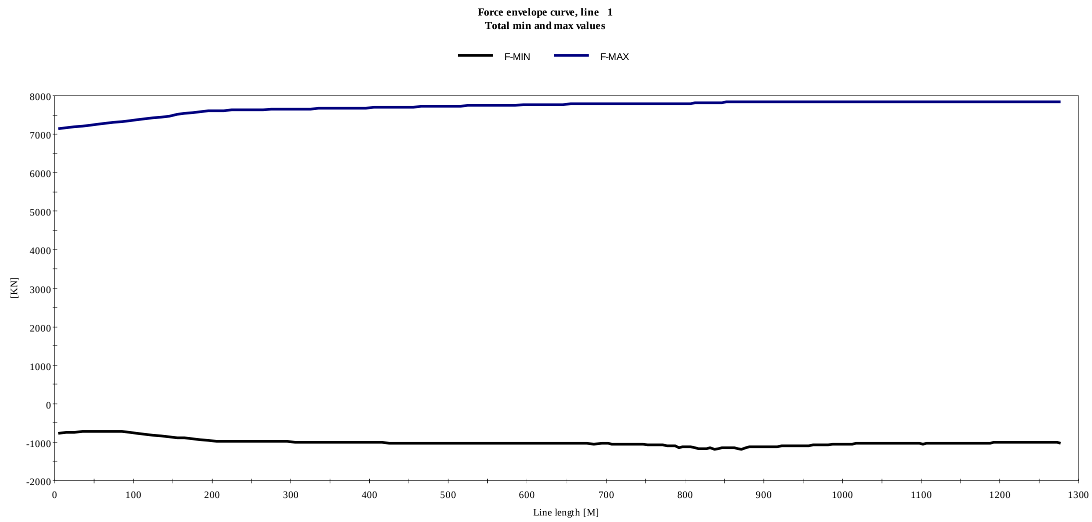

Figure 9.56 Maximum and minimum effective tension in mooring line – case1-tension 15%MBL –loaded condition - H=30m, Period 17s

The maximum and minimum effective tension in mooring line and the maximum and minimum line displacement in X, Y and Z directions are summarized in tables 9.20 and 9.21.
The following trends and behaviours are extracted:

- The lowest observed value for minimum dynamic axial force is obtained in highest seastate with wave height 30m and wave period 17s.
- The highest value for maximum dynamic axial force is obtained in highest seastate with wave height 30m and wave period 17s.
- The lowest value for minimum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 30m and wave period 17s.
- The highest value for maximum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 30m and wave period 17s.

Table 9-20 Force envelope curves for case1-tension 15%MBL –loaded -seastate case 2

SEASTATE	FORCE ENVELOPE CURVES		
	AXIAL FORCE		
	MIN DYNAMIC	STATIC FORCE	MAX DYNAMIC
H=30m,T= 13s	-1.76E+03	2.07E+03	1.42E+03
H=30m,T=14s	-2.47E+03	2.07E+03	2.40E+03
H=30m,T= 15s	-2.89E+03	2.07E+03	3.95E+03
H=30m,T= 16s	-2.90E+03	2.07E+03	5.33E+03
H=30m,T= 17s	-3.09E+03	2.07E+03	6.47E+03

Table 9-21 Displacement envelope curves for case1-tension 15%MBL –loaded -seastate case2

SEASTATE	DISPLACEMENT ENVELOPE CURVE					
	X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC
H=30m,T= 13s	-3.82E+00	5.28E+00	-3.14E+00	2.95E+00	-1.54E+01	1.57E+01
H=30m,T=14s	-5.71E+00	7.52E+00	-3.81E+00	3.51E+00	-1.66E+01	1.70E+01
H=30m,T= 15s	-7.42E+00	9.35E+00	-4.23E+00	3.85E+00	-1.72E+01	1.77E+01
H=30m,T= 16s	-8.94E+00	1.08E+01	-4.58E+00	4.10E+00	-1.75E+01	1.81E+01
H=30m,T= 17s	-1.03E+01	1.20E+01	-4.93E+00	4.30E+00	-1.76E+01	1.93E+01

9.4.2.2.3. Mooring line with tension 30%MBL- Regular wave H=15m, T=9-15s

For mooring line with tension 30%MBL, the maximum and minimum effective tension in regulare waves with wave height 15m and periods from 9s to 15s are shown in fgures 9.57 to 9.63.

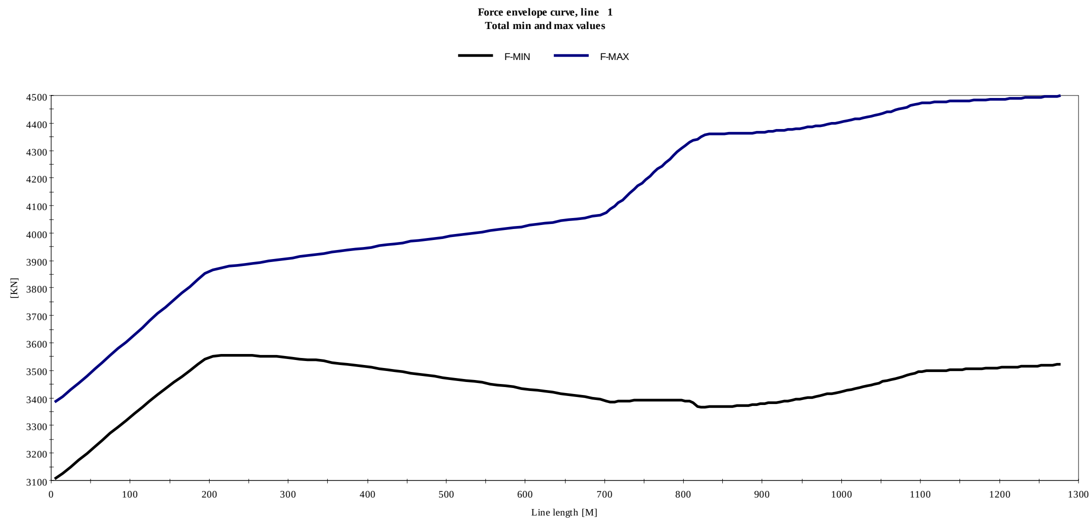

Figure 9.57 Maximum and minimum effective tension in mooring line – case1-tension 30%MBL –loaded condition - H=15m, Period 9s

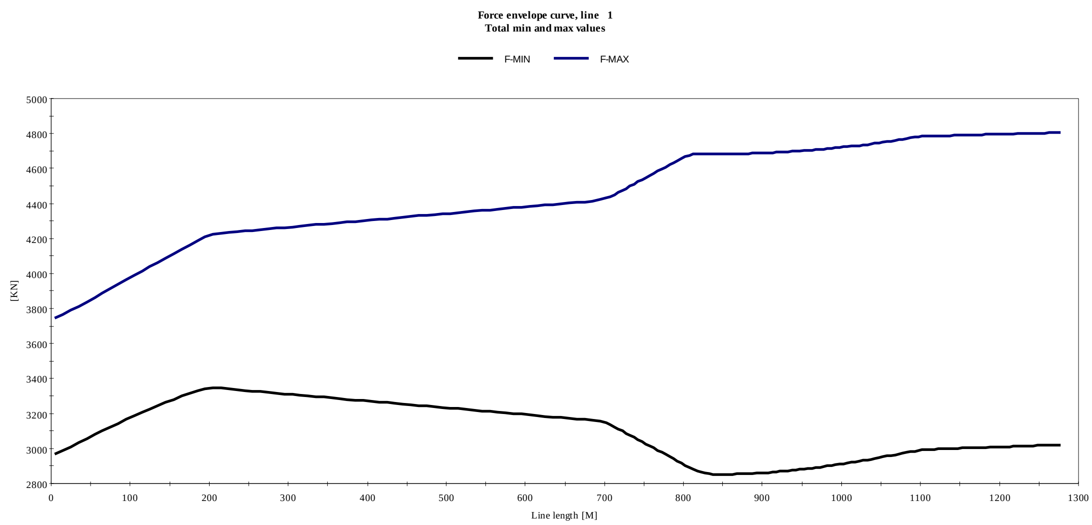

Figure 9.58 Maximum and minimum effective tension in mooring line – case1-tension 30%MBL –loaded condition - H=15m, Period 10s

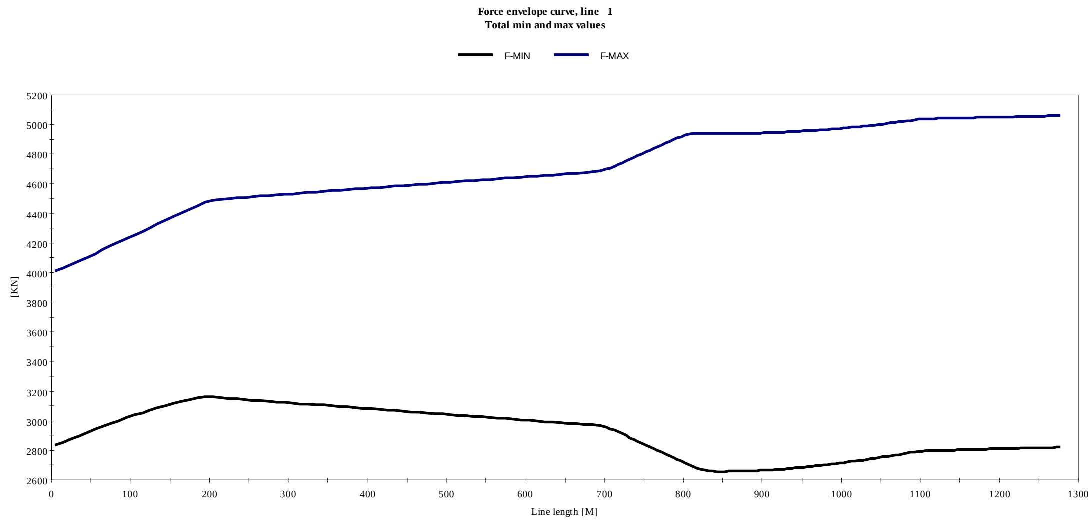

Figure 9.59 Maximum and minimum effective tension in mooring line – case1-tension 30%MBL –loaded condition - H=15m, Period 11s

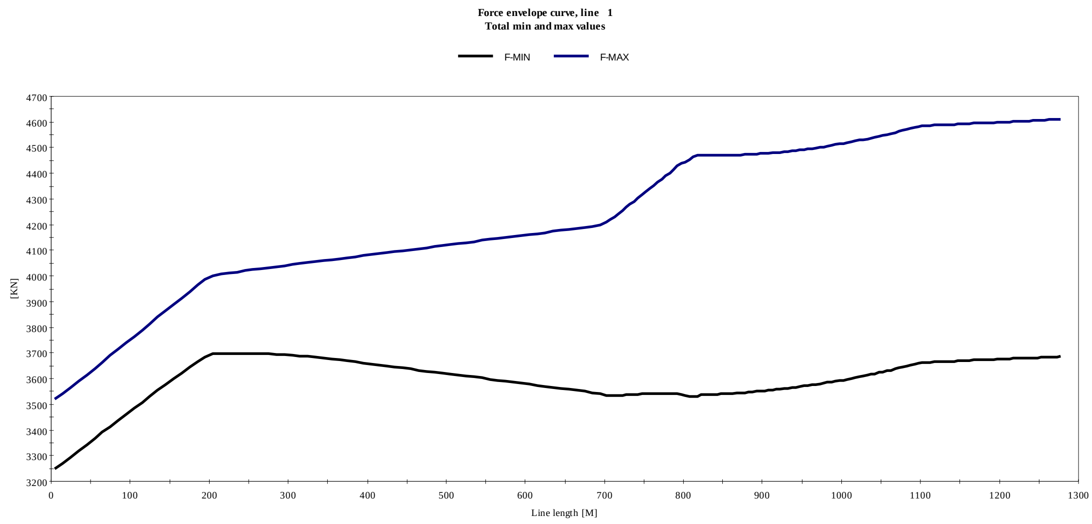

Figure 9.60 Maximum and minimum effective tension in mooring line – case1-tension 30%MBL –loaded condition - H=15m, Period 12s

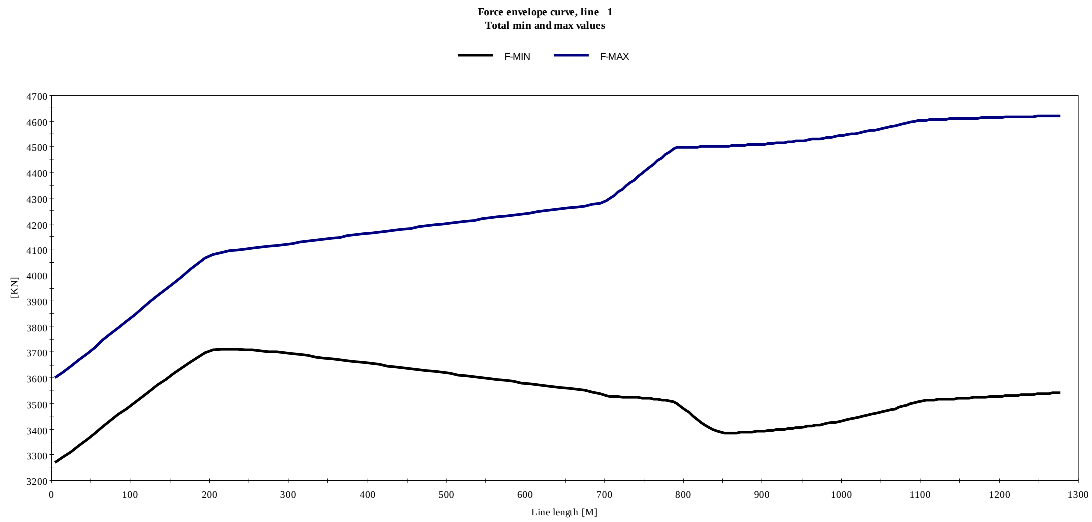

Figure 9.61 Maximum and minimum effective tension in mooring line – case1-tension 30%MBL –loaded condition - H=15m, Period 13s

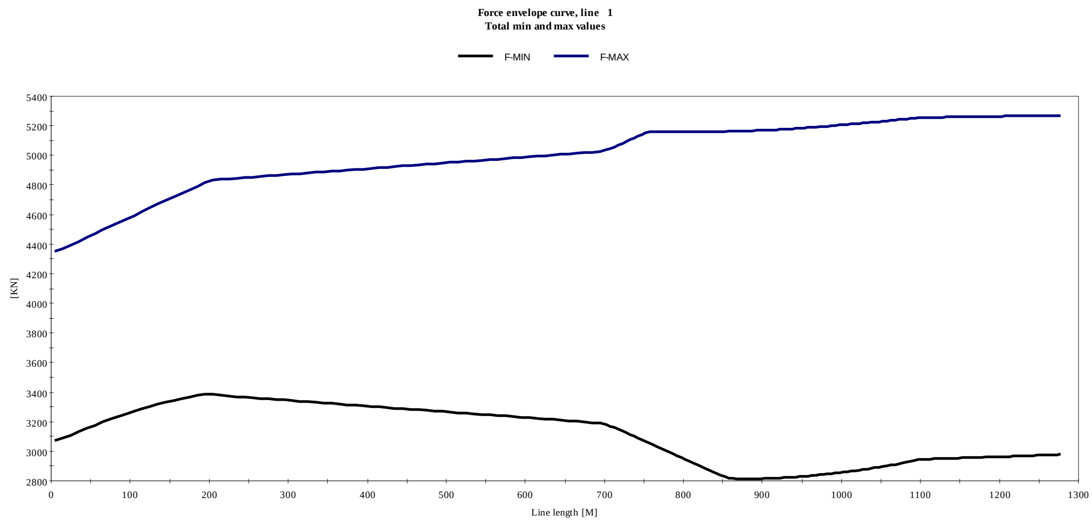

Figure 9.62 Maximum and minimum effective tension in mooring line – case1-tension 30%MBL –loaded condition - H=15m, Period 14s

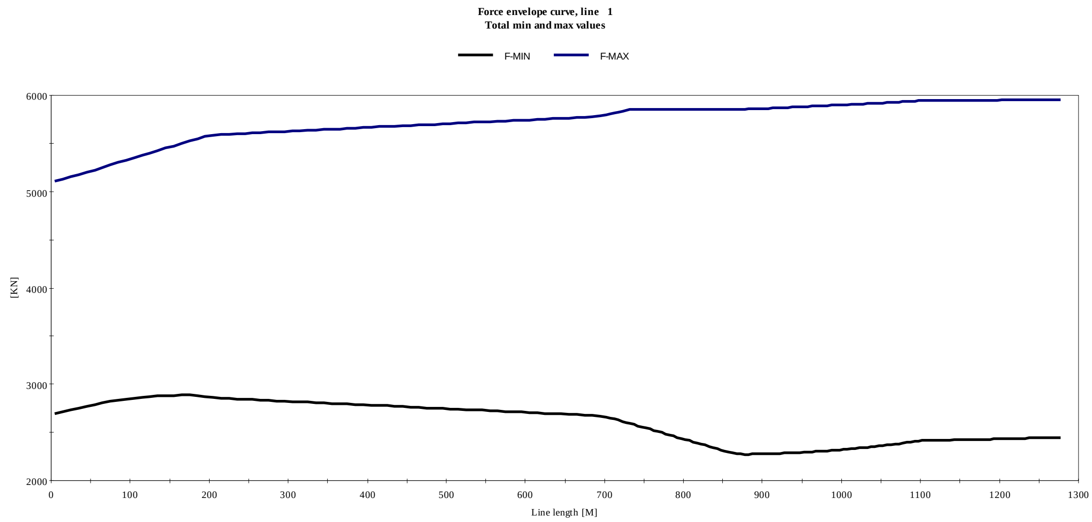

Figure 9.63 Maximum and minimum effective tension in mooring line – case1-tension 30%MBL –loaded condition - H=15m, Period 15s

The maximum and minimum effective tension in mooring line and the maximum and minimum line displacement in X, Y and Z directions are summarized in tables 9.22 and 9.23.

The following results and behaviours are observed:

- The lowest value for minimum dynamic axial force is obtained in highest seastate with wave height 15m and wave period 15s.
- The highest value for maximum dynamic axial force is obtained in highest seastate with wave height 15m and wave period 15s.
- The lowest value for minimum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 15m and wave period 15s.
- The highest value for maximum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 15m and wave period 15s.

Table 9-22 Force envelope curves for case1-tension 30%MBL –loaded -seastate case 1

SEASTATE	FORCE ENVELOPE CURVES		
	AXIAL FORCE		
	MIN DYNAMIC	STATIC FORCE	MAX DYNAMIC
H=15m,T= 9s	-6.05E+02	4.12E+03	4.08E+02
H=15m,T=10s	-1.12E+03	4.12E+03	7.66E+02
H=15m,T= 11s	-1.32E+03	4.12E+03	1.03E+03
H=15m,T= 12s	-4.35E+02	4.12E+03	5.42E+02
H=15m,T= 13s	-5.91E+02	4.12E+03	6.23E+02
H=15m,T= 14s	-1.17E+03	4.12E+03	1.37E+03
H=15m,T=15s	-1.71E+03	4.12E+03	2.13E+03

Table 9-23 Displacement envelope curves for case1-tension 30%MBL –loaded -seastate case 1

SEASTATE	DISPLACEMENT ENVELOPE CURVE					
	X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC
H=15m,T= 9s	-2.86E-01	4.78E-01	-6.09E-01	5.55E-01	-3.41E+00	2.82E+00
H=15m,T=10s	-6.23E-01	6.24E-01	-3.15E-01	3.13E-01	-4.96E+00	3.89E+00
H=15m,T= 11s	-7.04E-01	8.21E-01	-5.52E-01	5.50E-01	-6.22E+00	5.73E+00
H=15m,T= 12s	-1.05E+00	1.28E+00	-1.11E+00	1.08E+00	-6.94E+00	7.00E+00
H=15m,T= 13s	-2.08E+00	2.45E+00	-1.54E+00	1.49E+00	-7.75E+00	7.84E+00
H=15m,T= 14s	-3.08E+00	3.53E+00	-1.85E+00	1.78E+00	-8.36E+00	8.47E+00
H=15m,T=15s	-3.95E+00	4.43E+00	-2.05E+00	1.95E+00	-8.68E+00	8.81E+00

9.4.2.2.4. Mooring line with tension 30%MBL- Regular wave H=30m, T=13-17s

For mooring line with tension 30%MBL, the maximum and minimum effective tension in regulare waves with wave height 30m and periods from 13s to 17s are shown in fgures 9.64 to 9.68.

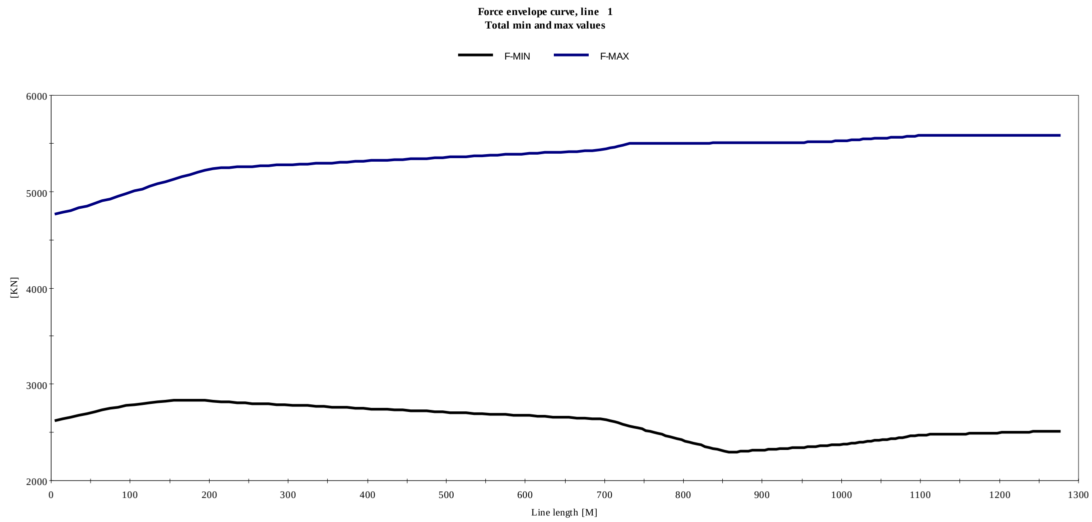

Figure 9.64 Maximum and minimum effective tension in mooring line – case1-tension 30%MBL –loaded condition - H=30m, Period 13s

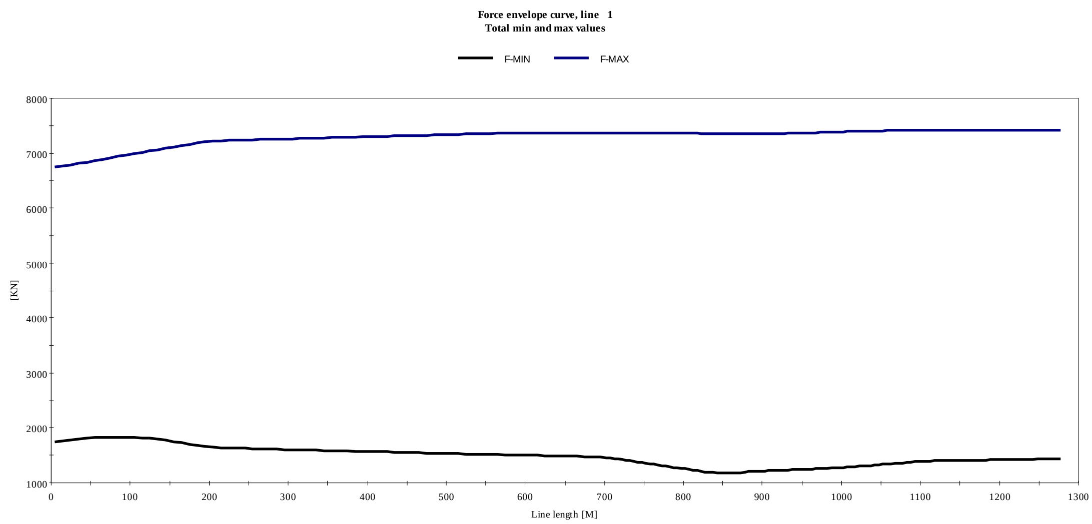

Figure 9.65 Maximum and minimum effective tension in mooring line – case1-tension 30%MBL –loaded condition - H=30m, Period 14s

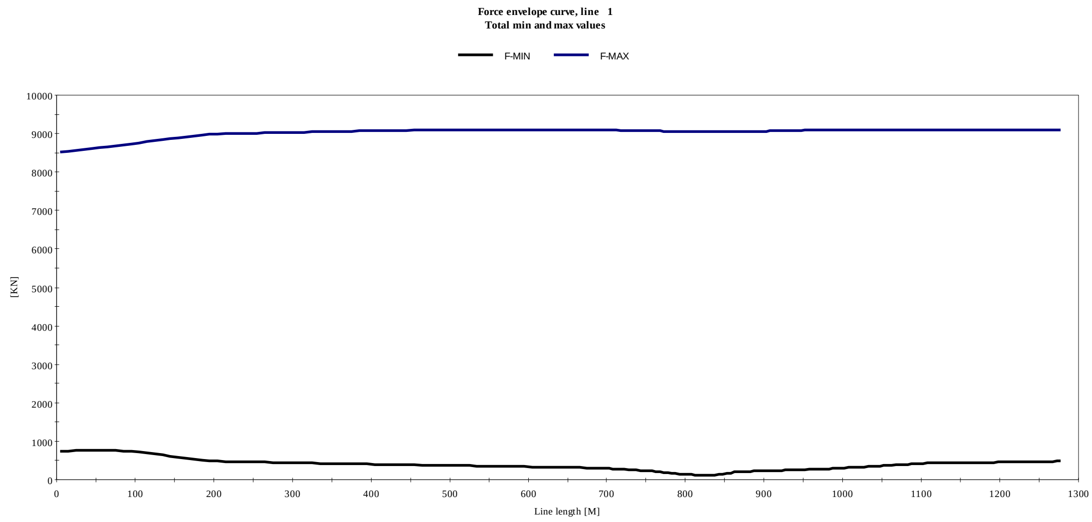

Figure 9.66 Maximum and minimum effective tension in mooring line – case1-tension 30%MBL –loaded condition - H=30m, Period 15s

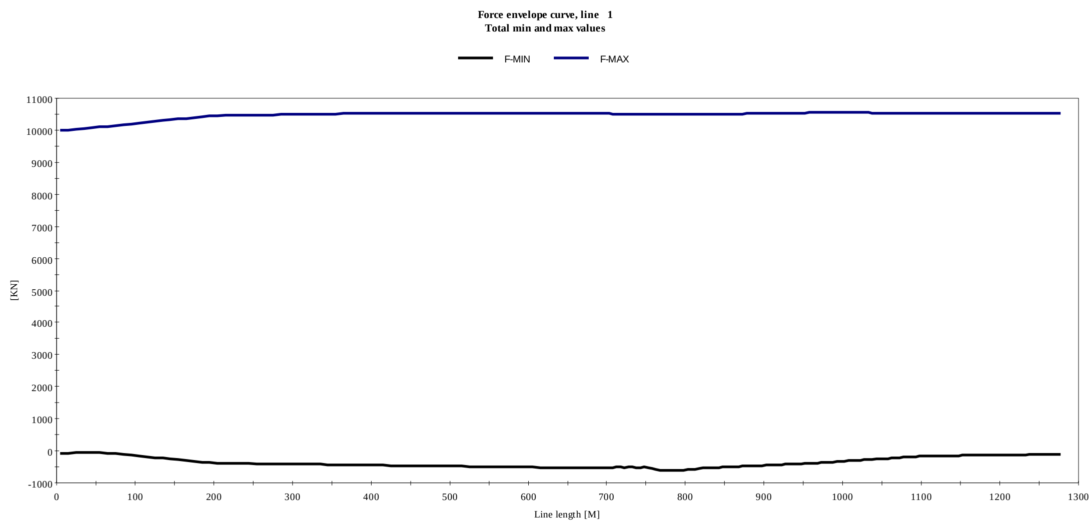

Figure 9.67 Maximum and minimum effective tension in mooring line – case1-tension 30%MBL –loaded condition - H=30m, Period 16s

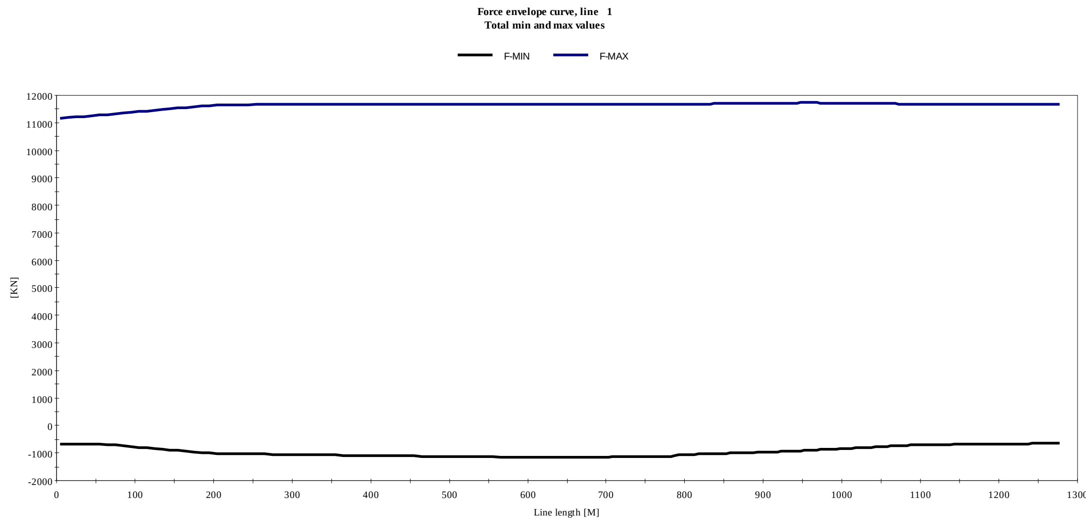

Figure 9.68 Maximum and minimum effective tension in mooring line – case1-tension 30%MBL –loaded condition - H=30m, Period 17s

The maximum and minimum effective tension in mooring line and the maximum and minimum line displacement in X, Y and Z directions are summarized in tables 9.24 and 9.25.

The following trends and behaviours are extracted:

- The lowest observed value for minimum dynamic axial force is obtained in highest seastate with wave height 30m and wave period 17s.
- The highest value for maximum dynamic axial force is obtained in highest seastate with wave height 30m and wave period 17s.
- The lowest value for minimum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 30m and wave period 17s.

The highest value for maximum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 30m and wave period 17s.

Table 9-24 Force envelope curves for case1-tension 30%MBL –loaded -seastate case 2

SEASTATE	FORCE ENVELOPE CURVES		
	AXIAL FORCE		
	MIN DYNAMIC	STATIC FORCE	MAX DYNAMIC
H=30m,T= 13s	-1.68E+03	4.12E+03	1.78E+03
H=30m,T=14s	-2.80E+03	4.12E+03	3.77E+03
H=30m,T= 15s	-3.86E+03	4.12E+03	5.54E+03
H=30m,T= 16s	-4.52E+03	4.12E+03	7.01E+03
H=30m,T= 17s	-5.00E+03	4.12E+03	8.19E+03

Table 9-25 Displacement envelope curves for case1-tension 30%MBL –loaded -seastate case2

SEASTATE	DISPLACEMENT ENVELOPE CURVE					
	X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC
H=30m,T= 13s	-3.82E+00	5.28E+00	-3.14E+00	2.95E+00	-1.54E+01	1.57E+01
H=30m,T=14s	-5.71E+00	7.52E+00	-3.81E+00	3.51E+00	-1.66E+01	1.70E+01
H=30m,T= 15s	-7.42E+00	9.35E+00	-4.23E+00	3.85E+00	-1.72E+01	1.77E+01
H=30m,T= 16s	-8.94E+00	1.08E+01	-4.58E+00	4.10E+00	-1.75E+01	1.81E+01
H=30m,T= 17s	-1.03E+01	1.20E+01	-4.93E+00	4.30E+00	-1.76E+01	1.82E+01

9.4.2.2.5. Mooring line with tension 45%MBL- Regular wave H=15m, T=9-15

For mooring line with tension 45%MBL, the maximum and minimum effective tension in regulare waves with wave height 15m and periods from 9s to 15s are shown in fgures 9.69 to 9.75.

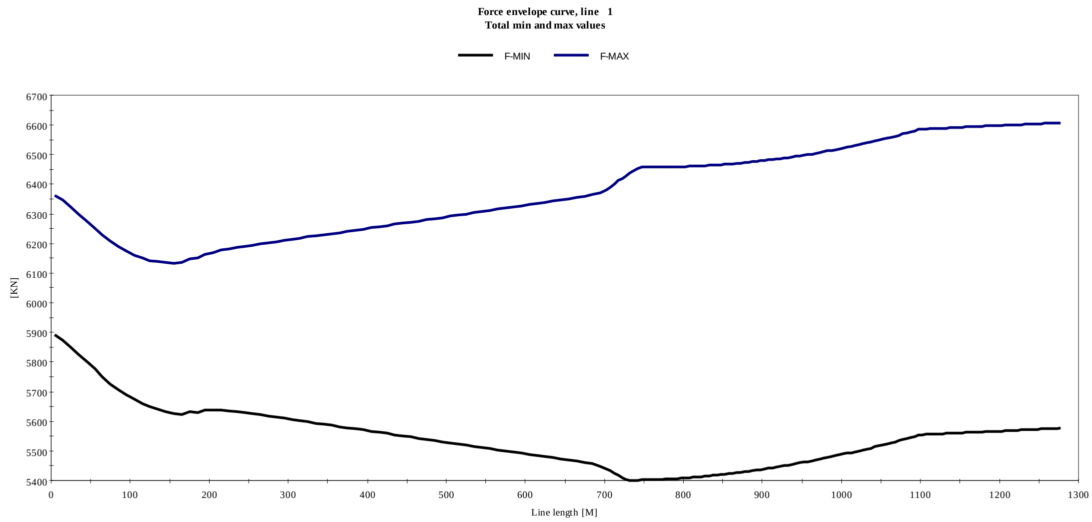

Figure 9.69 Maximum and minimum effective tension in mooring line – case1-tension 45%MBL –loaded condition - H=15m, Period 9s

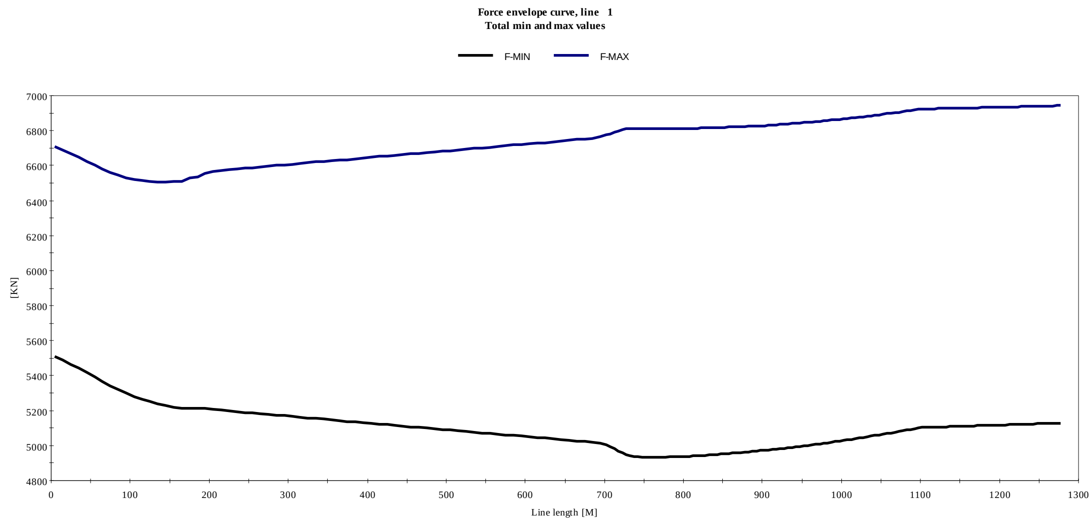

Figure 9.70 Maximum and minimum effective tension in mooring line – case1-tension 45%MBL –loaded condition - H=15m, Period 10s

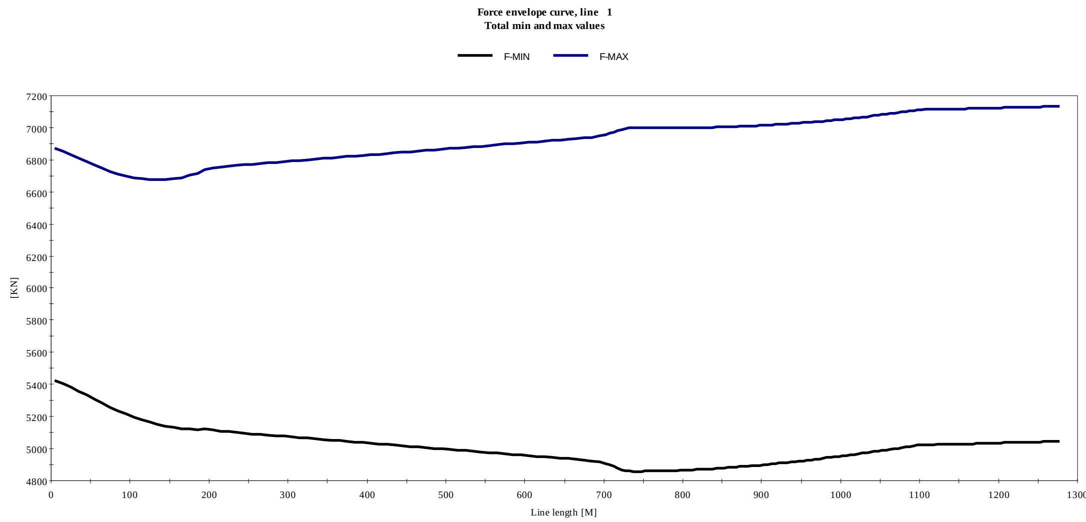

Figure 9.71 Maximum and minimum effective tension in mooring line – case1-tension 45%MBL –loaded condition - H=15m, Period 11s

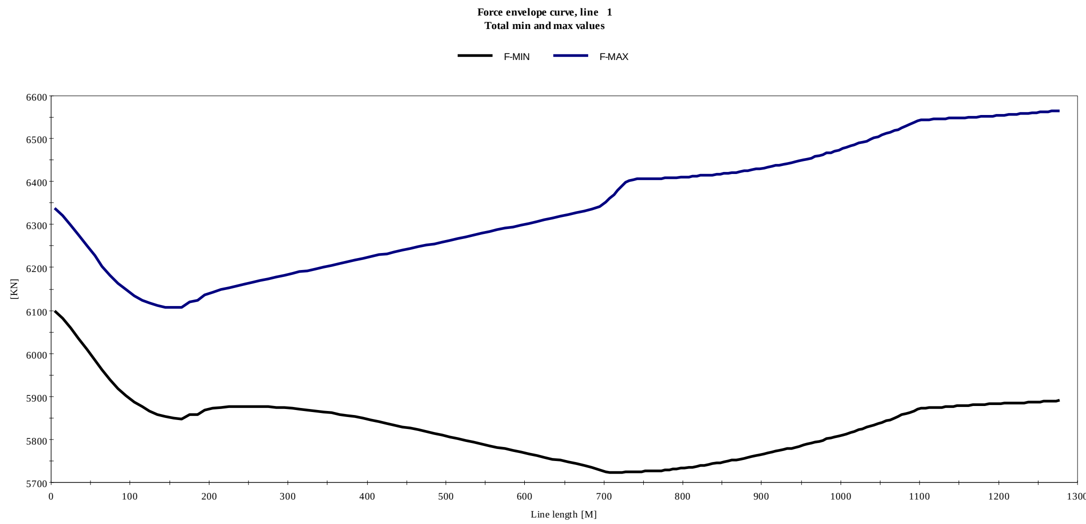

Figure 9.72 Maximum and minimum effective tension in mooring line – case1-tension 45%MBL –loaded condition - H=15m, Period 12s

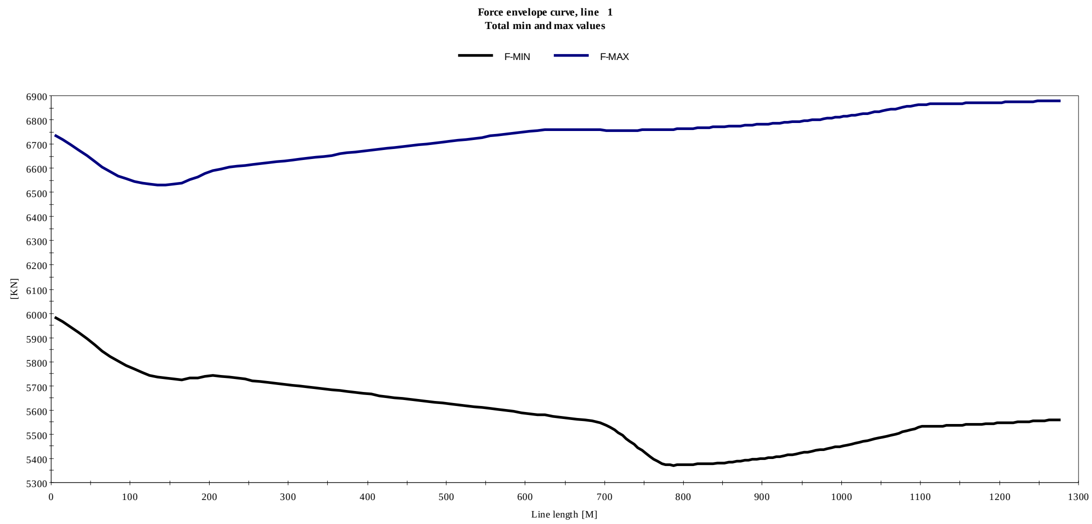

Figure 9.73 Maximum and minimum effective tension in mooring line – case1-tension 45%MBL –loaded condition - H=15m, Period 13s

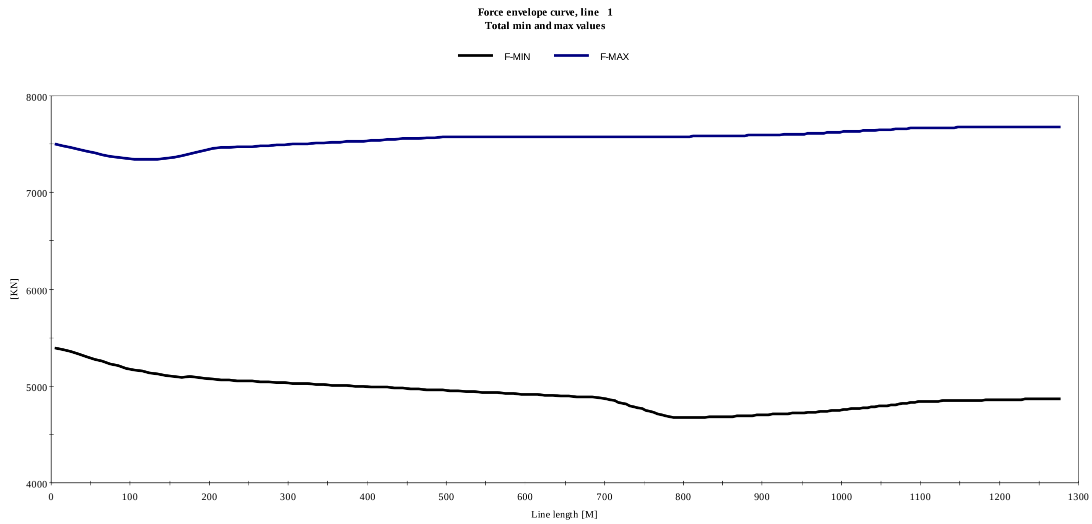

Figure 9.74 Maximum and minimum effective tension in mooring line – case1-tension 45%MBL –loaded condition - H=15m, Period 14s

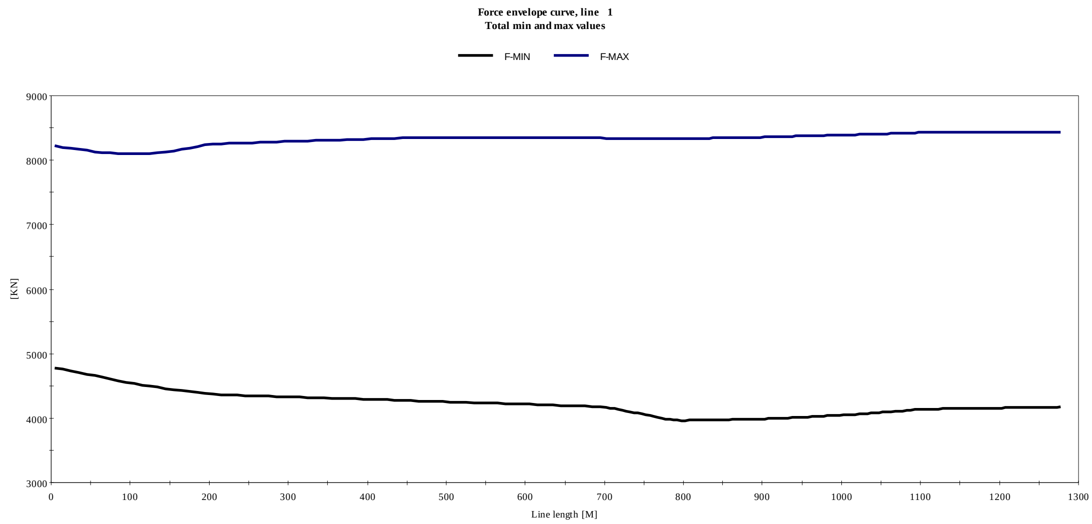

Figure 9.75 Maximum and minimum effective tension in mooring line – case1-tension 45%MBL –loaded condition - H=15m, Period 15s

The maximum and minimum effective tension in mooring line and the maximum and minimum line displacement in X, Y and Z directions are summarized in tables 9.26 and 9.27.

The following results and behaviours are observed:

- The lowest value for minimum dynamic axial force is obtained in highest seastate with wave height 15m and wave period 15s.
- The highest value for maximum dynamic axial force is obtained in highest seastate with wave height 15m and wave period 15s.
- The lowest value for minimum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 15m and wave period 15s.

The highest value for maximum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 15m and wave period 15s.

Table 9-26 Force envelope curves for case1-tension 45%MBL –loaded -seastate case 1

SEASTATE	FORCE ENVELOPE CURVES		
	AXIAL FORCE		
	MIN DYNAMIC	STATIC FORCE	MAX DYNAMIC
H=15m,T= 9s	-5.87E+02	6.15E+03	4.70E+02
H=15m,T=10s	-1.06E+03	6.15E+03	8.49E+02
H=15m,T= 11s	-1.13E+03	6.15E+03	1.03E+03
H=15m,T= 12s	-2.64E+02	6.15E+03	4.29E+02
H=15m,T= 13s	-6.20E+02	6.15E+03	8.75E+02
H=15m,T= 14s	-1.32E+03	6.15E+03	1.74E+03
H=15m,T=15s	-2.03E+03	6.15E+03	2.53E+03

Table 9-27 Displacement envelope curves for case1-tension 45%MBL –loaded -seastate case 1

SEASTATE	DISPLACEMENT ENVELOPE CURVE					
	X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC
H=15m,T= 9s	-3.15E-01	4.07E-01	-6.09E-01	5.55E-01	-2.94E+00	2.73E+00
H=15m,T=10s	-6.23E-01	6.24E-01	-3.15E-01	3.13E-01	-3.98E+00	3.64E+00
H=15m,T= 11s	-7.29E-01	7.47E-01	-5.52E-01	5.50E-01	-5.71E+00	5.73E+00
H=15m,T= 12s	-1.05E+00	1.28E+00	-1.11E+00	1.08E+00	-6.94E+00	7.00E+00
H=15m,T= 13s	-2.08E+00	2.45E+00	-1.54E+00	1.49E+00	-7.75E+00	7.84E+00
H=15m,T= 14s	-3.08E+00	3.53E+00	-1.85E+00	1.78E+00	-8.36E+00	8.47E+00
H=15m,T=15s	-3.95E+00	4.43E+00	-2.05E+00	1.95E+00	-8.68E+00	8.81E+00

9.4.2.2.6. Mooring line with tension 45%MBL- Regular wave H=30m, T=13-17s

For mooring line with tension 45%MBL, the maximum and minimum effective tension in regulare waves with wave height 30m and periods from 13s to 17s are shown in fgures 9.76 to 9.80.

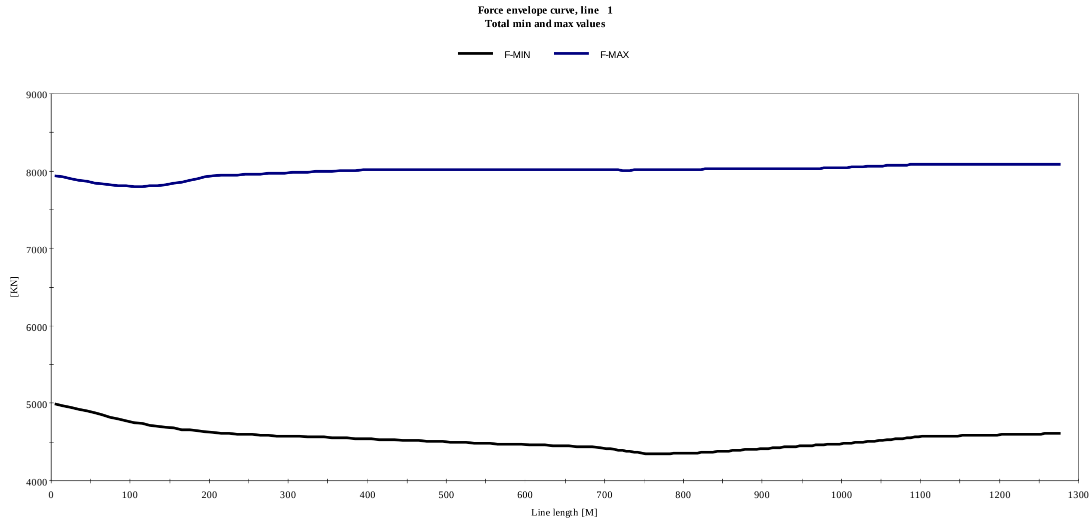

Figure 9.76 Maximum and minimum effective tension in mooring line – case1-tension 45%MBL –loaded condition - H=30m, Period 13s

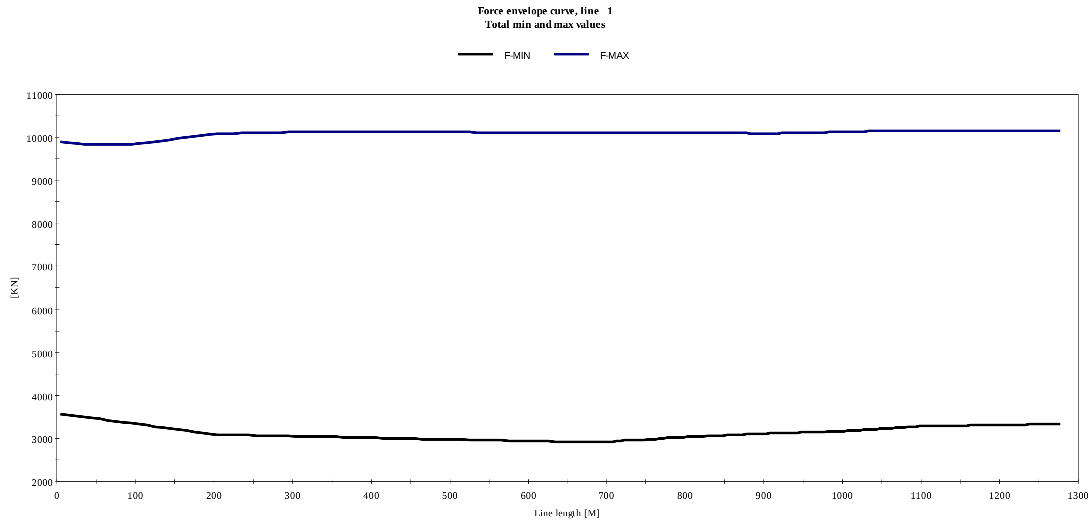

Figure 9.77 Maximum and minimum effective tension in mooring line – case1-tension 45%MBL –loaded condition - H=30m, Period 14s

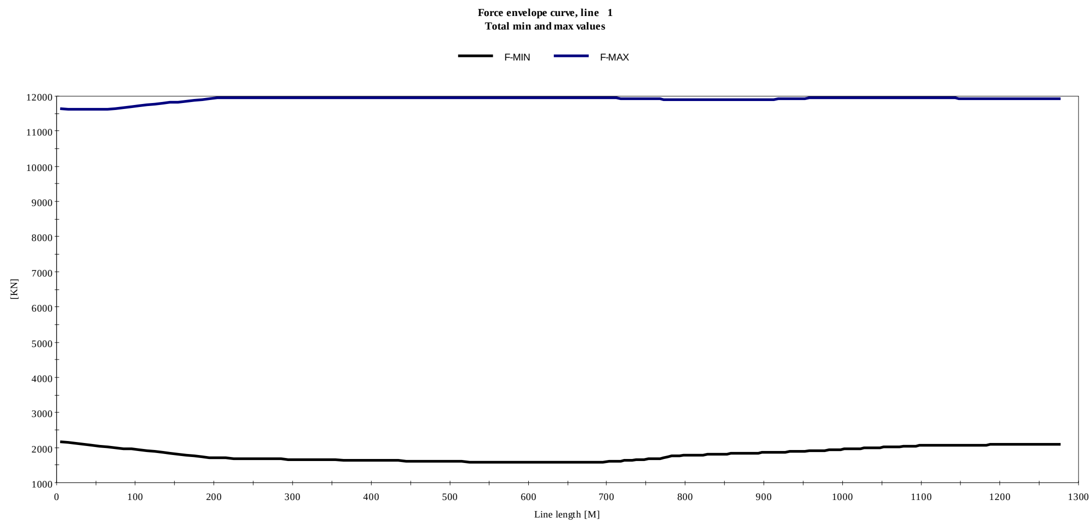

Figure 9.78 Maximum and minimum effective tension in mooring line – case1-tension 45%MBL –loaded condition - H=30m, Period 15s

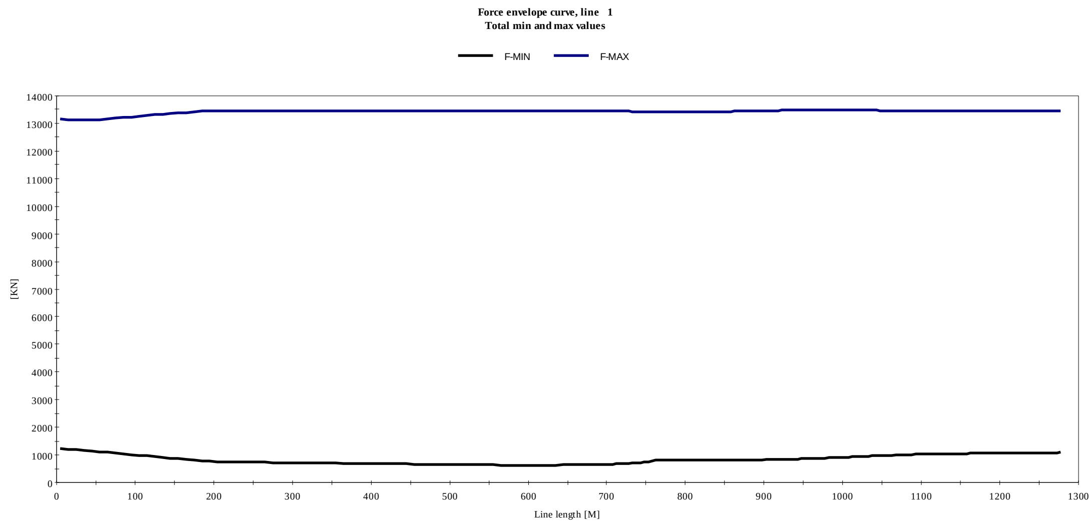

Figure 9.79 Maximum and minimum effective tension in mooring line – case1-tension 45%MBL –loaded condition - H=30m, Period 16s

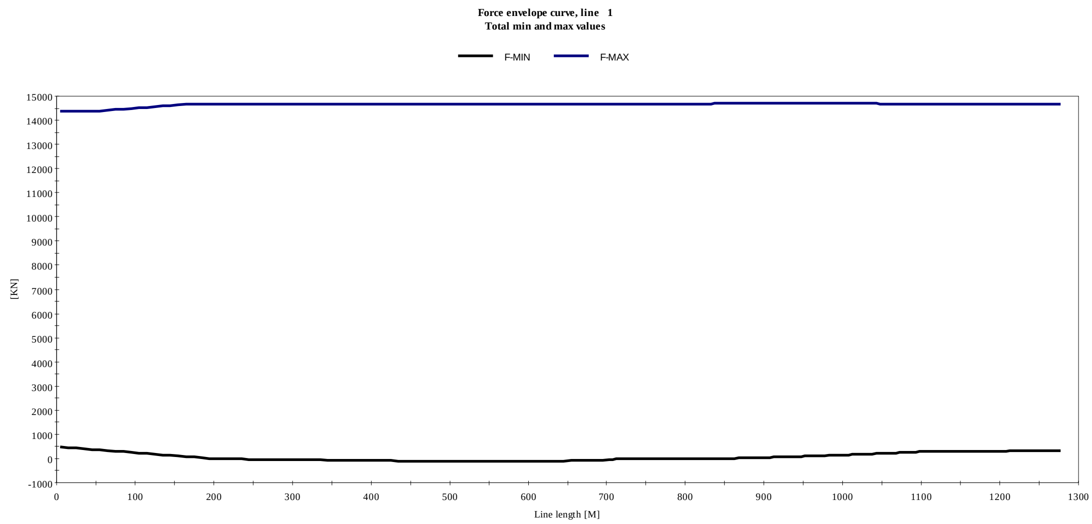

Figure 9.80 Maximum and minimum effective tension in mooring line – case1-tension 45%MBL –loaded condition - H=30m, Period 17s

The maximum and minimum effective tension in mooring line and the maximum and minimum line displacement in X, Y and Z directions are summarized in tables 9.28 and 9.29.

The following trends and behaviours are extracted:

- The lowest observed value for minimum dynamic axial force is obtained in highest seastate with wave height 30m and wave period 17s.
- The highest value for maximum dynamic axial force is obtained in highest seastate with wave height 30m and wave period 17s.
- The lowest value for minimum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 30m and wave period 17s.
- The highest value for maximum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 30m and wave period 17s.

Table 9-28 Force envelope curves for case1-tension 45%MBL –loaded -seastate case 2

SEASTATE	FORCE ENVELOPE CURVES		
	AXIAL FORCE		
	MIN DYNAMIC	STATIC FORCE	MAX DYNAMIC
H=30m,T= 13s	-1.64E+03	6.15E+03	2.22E+03
H=30m,T=14s	-3.03E+03	6.15E+03	4.36E+03
H=30m,T= 15s	-4.34E+03	6.15E+03	6.21E+03
H=30m,T= 16s	-5.29E+03	6.15E+03	7.72E+03
H=30m,T= 17s	-6.01E+03	6.15E+03	8.95E+03

Table 9-29 Displacement envelope curves for case1-tension 45%MBL –loaded -seastate case2

SEASTATE	DISPLACEMENT ENVELOPE CURVE					
	X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC
H=30m,T= 13s	-3.82E+00	5.28E+00	-3.14E+00	2.95E+00	-1.54E+01	1.57E+01
H=30m,T=14s	-5.71E+00	7.52E+00	-3.81E+00	3.51E+00	-1.66E+01	1.70E+01
H=30m,T= 15s	-7.42E+00	9.35E+00	-4.23E+00	3.85E+00	-1.72E+01	1.77E+01
H=30m,T= 16s	-8.94E+00	1.08E+01	-4.58E+00	4.10E+00	-1.75E+01	1.81E+01
H=30m,T= 17s	-1.03E+01	1.20E+01	-4.93E+00	4.30E+00	-1.76E+01	1.82E+01

9.4.3. Case 2- ballasted condition

9.4.3.1. Static analysis

Static analysis was carried out for mooring line when the tension on line is 15%, 30% and 45% of MBL (minimum breaking load), two sets of regular waves with different wave period and wave heights applied on system and vessel is in ballasted condition. Mooring line shapes in XZ plane are shown in figures 9.81., 9.82., 9.83. With comparison between these figures, when the tension on the mooring line increased the seafloor interaction will decreased.

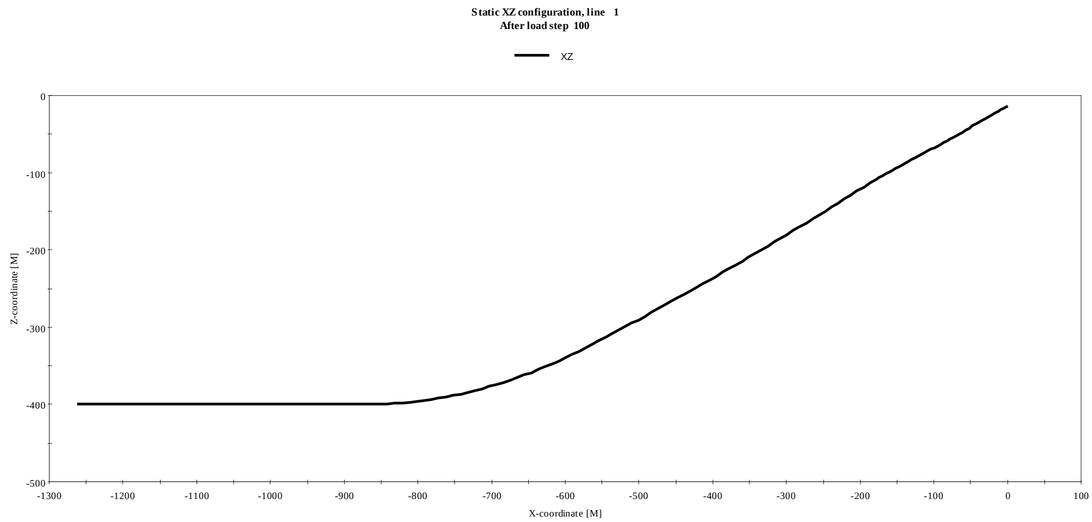

Figure 9.81 Mooring line shape in XZ plane with tension 15% MBL-case2-ballasted

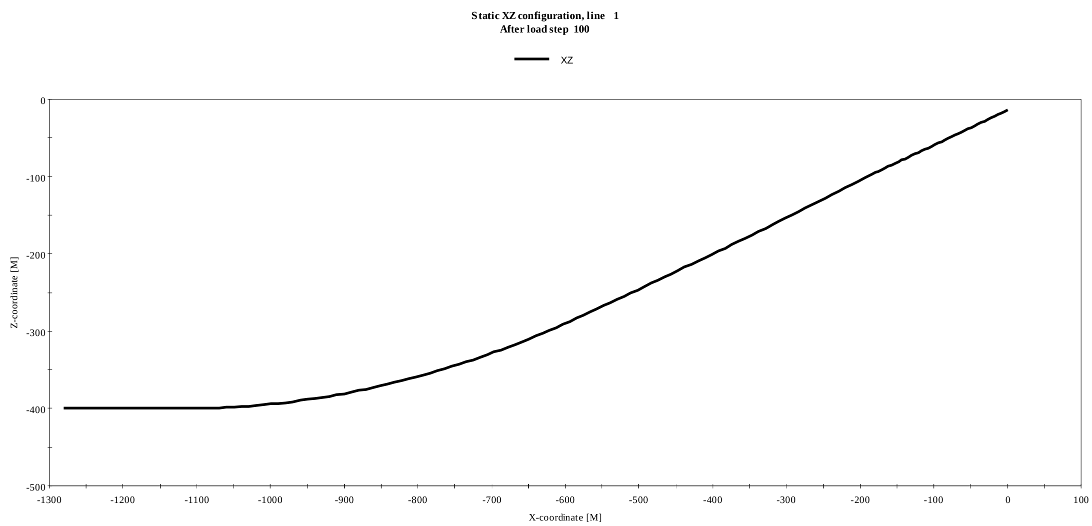

Figure 9.82 Mooring line shape in XZ plane with tension 30% MBL-case2-ballasted

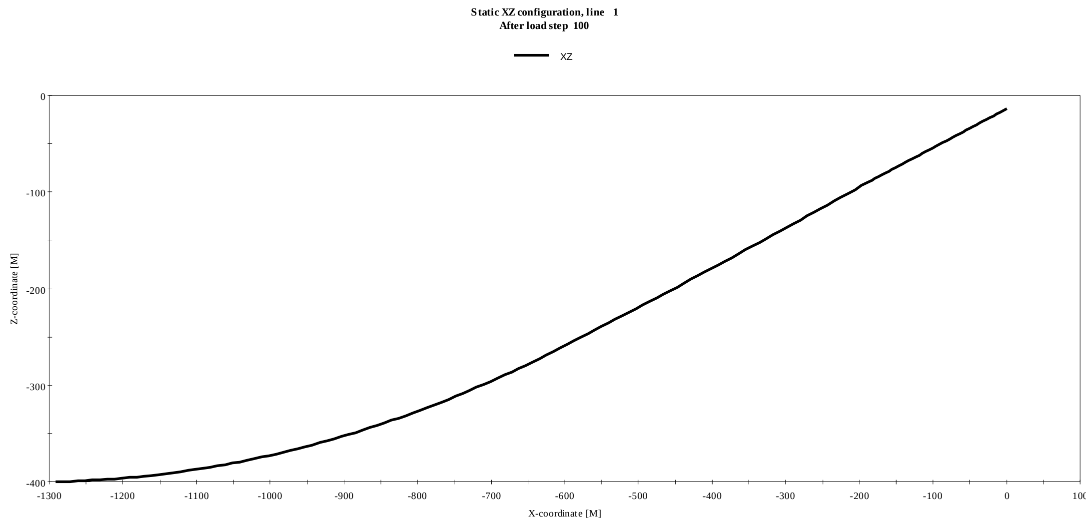

Figure 9.83 Mooring line shape in XZ plane with tension 45% MBL-case2-ballasted

9.4.3.2. Dynamic analysis

The maximum and minimum effective tension of the mooring line for three line configuration when the tension applied on line is 15%, 30% and 45% are shown below. Also, in this section all line displacements are summerized in following tables.

9.4.3.2.1. Mooring line with tension 15%MBL- Regular wave H=15m, T=9-15s

For mooring line with tension 15%MBL, the maximum and minimum effective tension in regulare waves with wave height 15m and periods from 9s to 15s are shown in fgures 9.84 to 9.90.

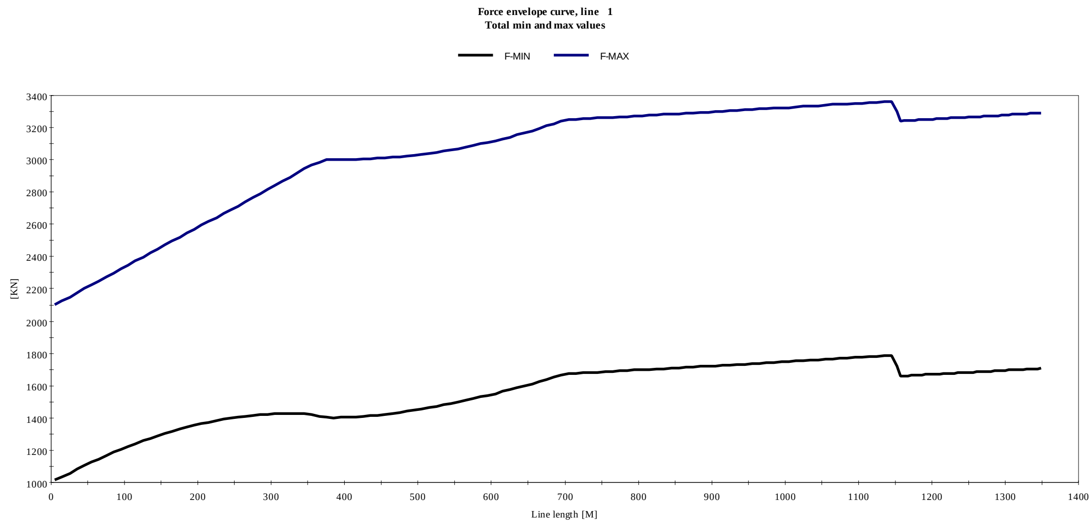

Figure 9.84 Maximum and minimum effective tension in mooring line – case2-tension 15%MBL –ballasted condition - H=15m, Period 9s

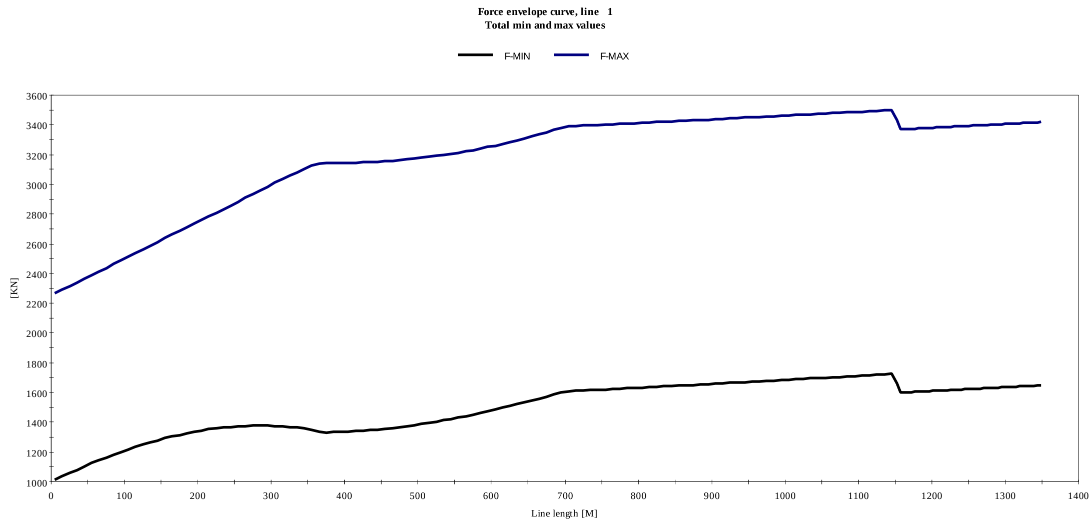

Figure 9.85 Maximum and minimum effective tension in mooring line – case2-tension 15%MBL –ballasted condition - H=15m, Period 10s

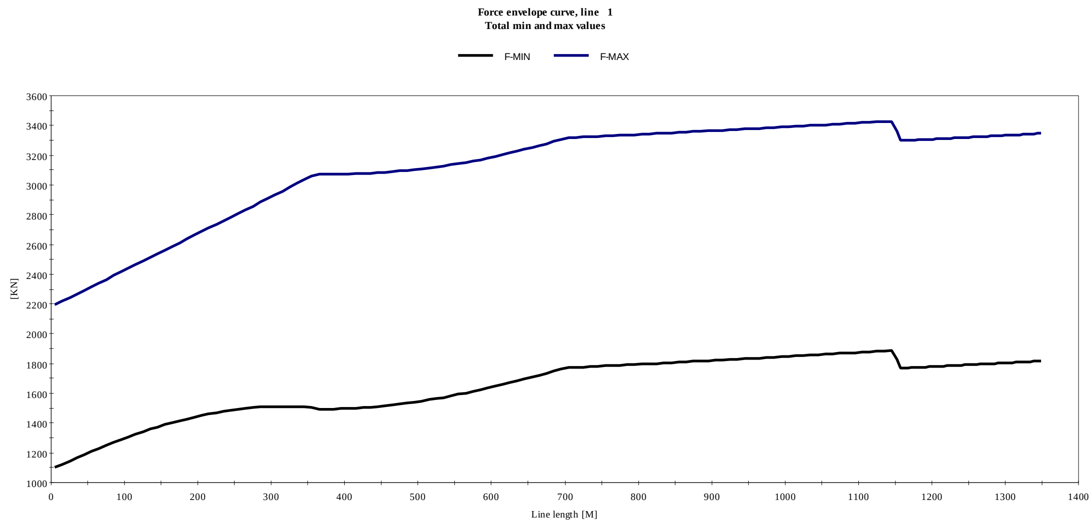

Figure 9.86 Maximum and minimum effective tension in mooring line – case2-tension 15%MBL –ballasted condition - H=15m, Period 11s

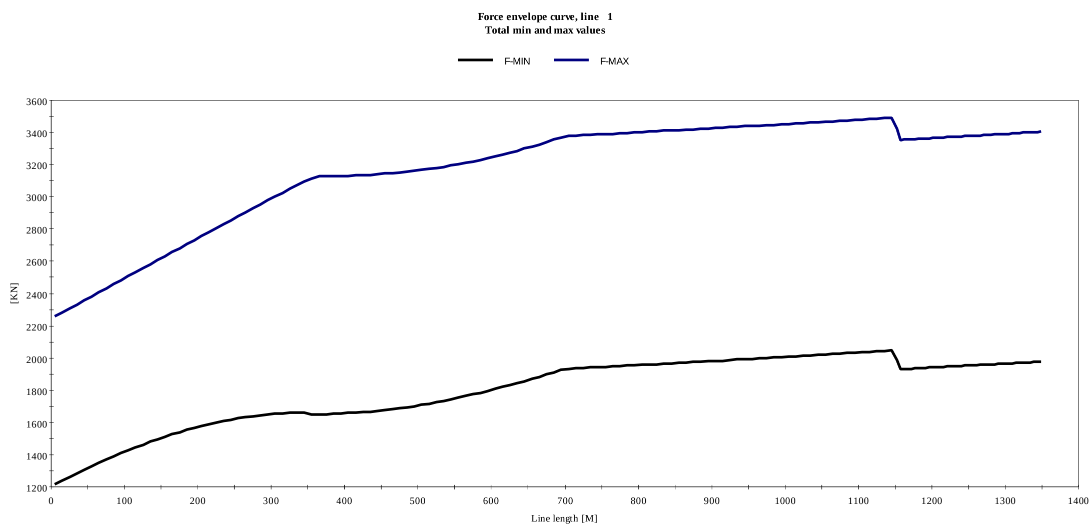

Figure 9.87 Maximum and minimum effective tension in mooring line – case2-tension 15%MBL –ballasted condition - H=15m, Period 12s

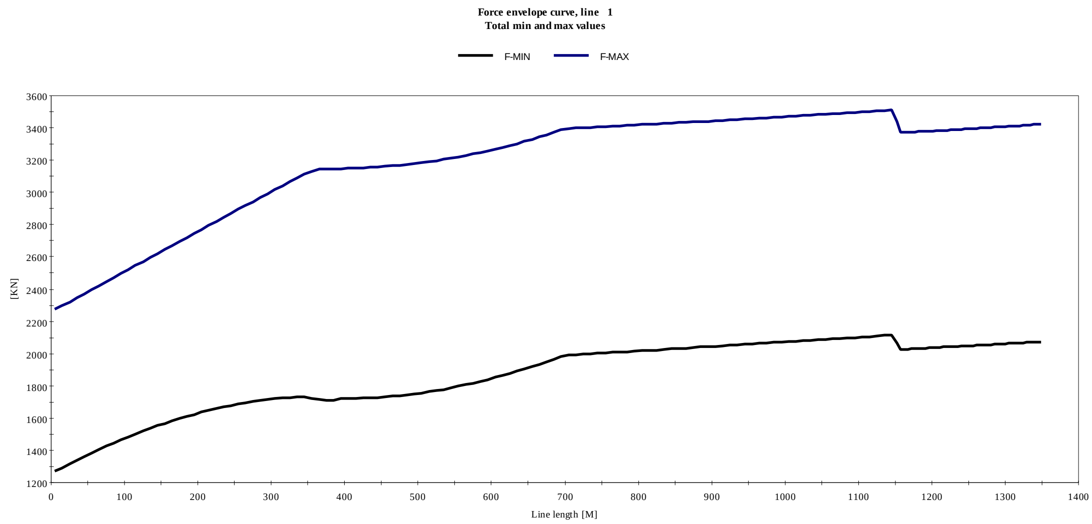

Figure 9.88 Maximum and minimum effective tension in mooring line – case2-tension 15%MBL –ballasted condition - H=15m, Period 13s

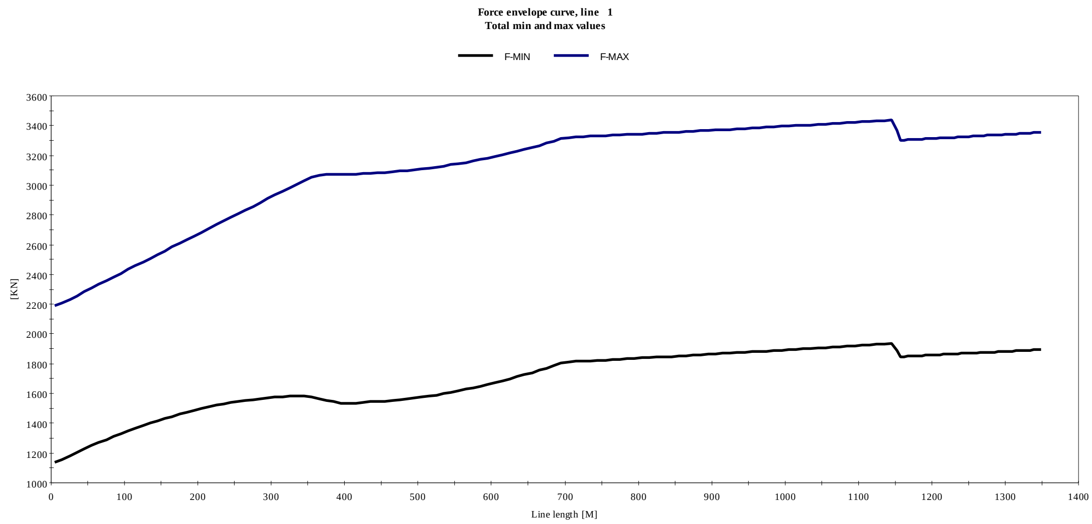

Figure 9.89 Maximum and minimum effective tension in mooring line – case2-tension 15%MBL –ballasted condition - H=15m, Period 14s

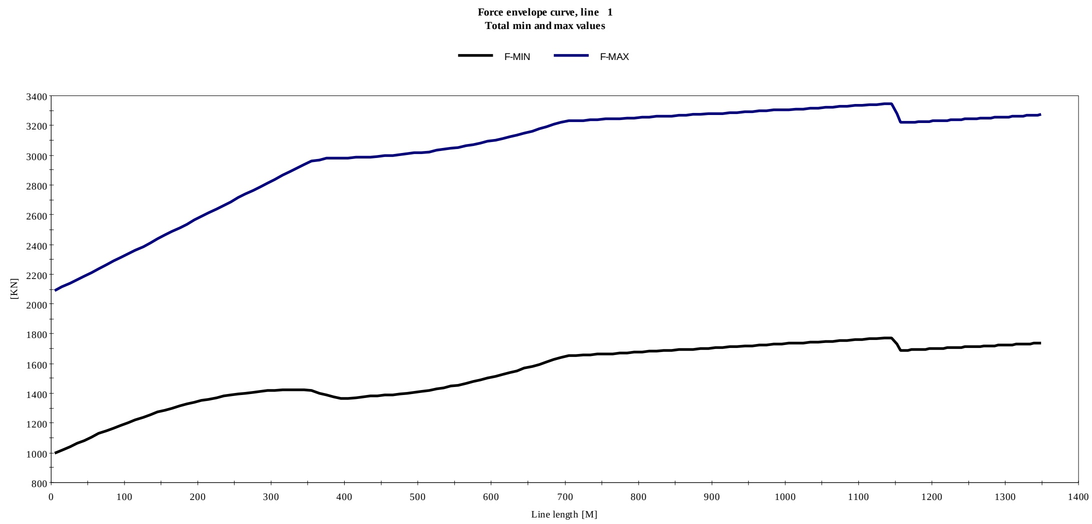

Figure 9.90 Maximum and minimum effective tension in mooring line – case2-tension 15%MBL –ballasted condition - H=15m, Period 15s

The maximum and minimum effective tension in mooring line and the maximum and minimum line displacement in X, Y and Z directions are summarized in tables 9.30 and 9.31.

The following results and behaviours are observed:

- The lowest value for minimum dynamic axial force is obtained in highest seastate with wave height 15m and wave period 15s.
- The highest value for maximum dynamic axial force is obtained in highest seastate with wave height 15m and wave period 15s.
- The lowest value for minimum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 15m and wave period 15s.
- The highest value for maximum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 15m and wave period 15s.

Table 9-30 Force envelope curves for case2-tension 15%MBL –ballasted -seastate case 1

SEASTATE	FORCE ENVELOPE CURVES		
	AXIAL FORCE		
	MIN DYNAMIC	STATIC FORCE	MAX DYNAMIC
H=15m,T= 9s	-8.57E+02	2.63E+03	8.22E+02
H=15m,T=10s	-9.16E+02	2.63E+03	9.84E+02
H=15m,T= 11s	-7.48E+02	2.63E+03	9.14E+02
H=15m,T= 12s	-5.87E+02	2.63E+03	9.79E+02
H=15m,T= 13s	-5.25E+02	2.63E+03	9.92E+02
H=15m,T= 14s	-7.10E+02	2.63E+03	9.03E+02
H=15m,T=15s	-8.78E+02	2.63E+03	8.09E+02

Table 9-31 Displacement envelope curves for case2-tension 15%MBL –ballasted -seastate case 1

SEASTATE	DISPLACEMENT ENVELOPE CURVE					
	X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC
H=15m,T= 9s	-2.51E+00	2.33E+00	-3.89E-01	3.48E-01	-4.19E+00	4.57E+00
H=15m,T=10s	-3.33E+00	2.87E+00	-6.13E-02	8.35E-02	-4.93E+00	5.56E+00
H=15m,T= 11s	-3.36E+00	2.99E+00	-6.09E-01	6.06E-01	-5.13E+00	5.72E+00
H=15m,T= 12s	-3.04E+00	2.83E+00	-1.12E+00	1.07E+00	-6.84E+00	6.90E+00
H=15m,T= 13s	-2.61E+00	3.08E+00	-1.47E+00	1.35E+00	-8.19E+00	8.29E+00
H=15m,T= 14s	-3.63E+00	4.16E+00	-1.64E+00	1.45E+00	-8.86E+00	8.98E+00
H=15m,T=15s	-4.46E+00	4.97E+00	-1.58E+00	1.32E+00	-9.05E+00	9.17E+00

9.4.3.2.2. Mooring line with tension 15%MBL- Regular wave H=30m, T=13-17s

For mooring line with tension 15%MBL, the maximum and minimum effective tension in regulare waves with wave height 30m and periods from 13s to 17s are shown in figures 9.91 to 9.95.

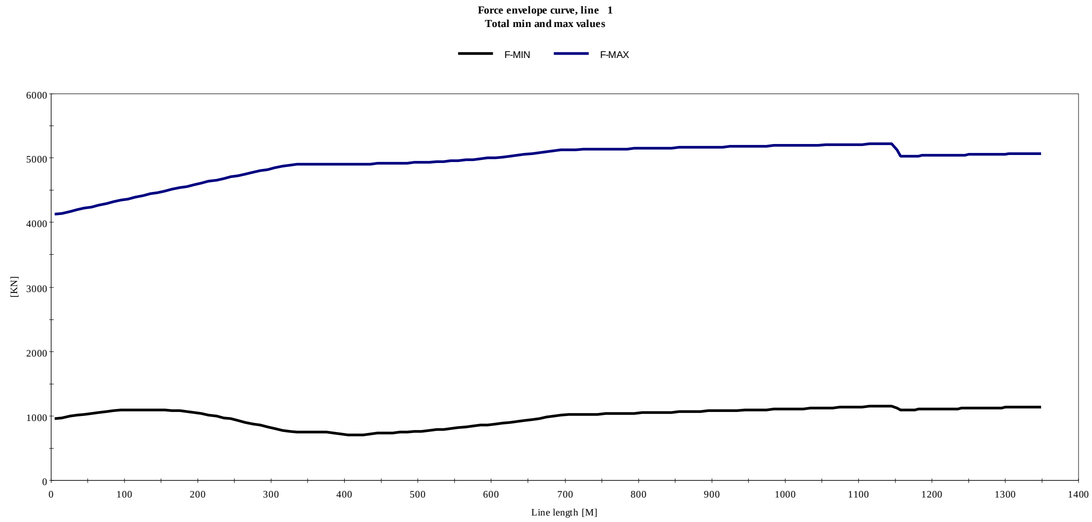

Figure 9.91 Maximum and minimum effective tension in mooring line – case2-tension 15%MBL –ballasted condition - H=30m, Period 13s

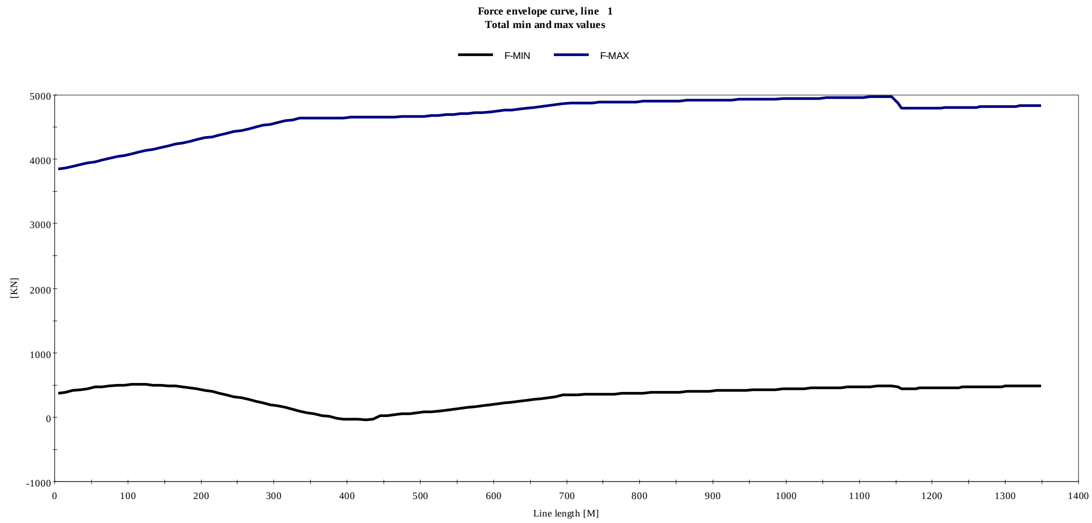

Figure 9.92 Maximum and minimum effective tension in mooring line – case2-tension 15%MBL –ballasted condition - H=30m, Period 14s

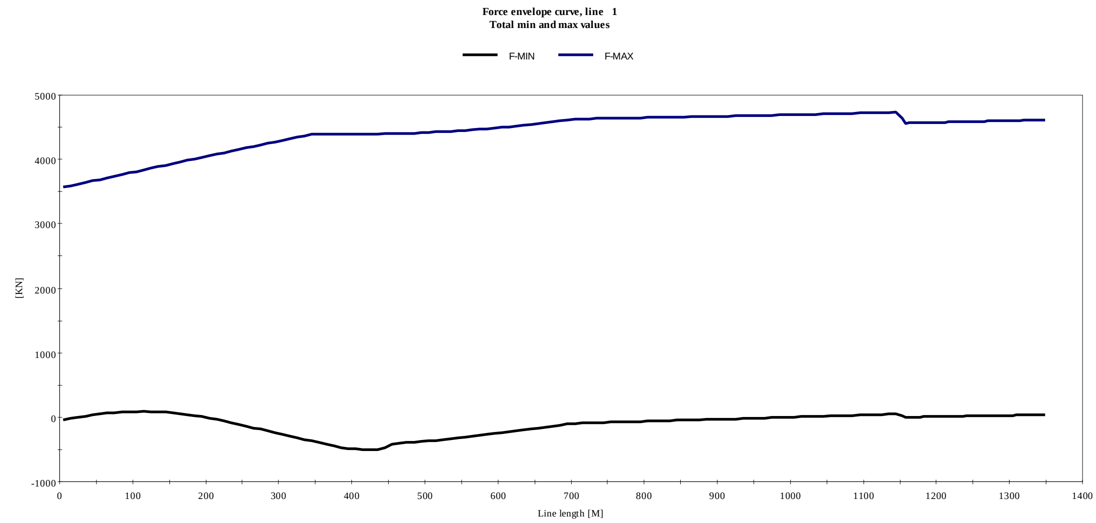

Figure 9.93 Maximum and minimum effective tension in mooring line – case2-tension 15%MBL –ballasted condition - H=30m, Period 15s

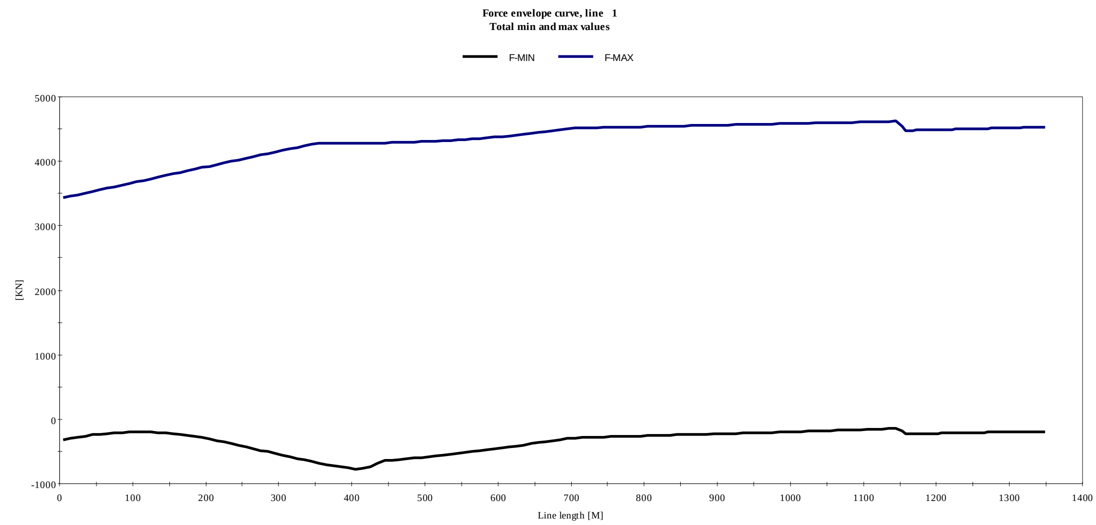

Figure 9.94 Maximum and minimum effective tension in mooring line – case2-tension 15%MBL –ballasted condition - H=30m, Period 16s

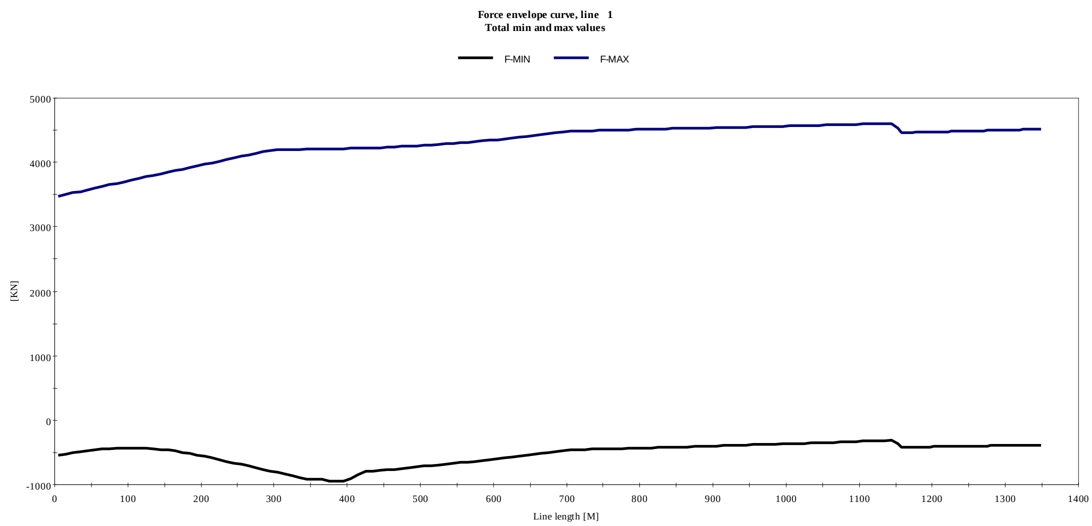

Figure 9.95 Maximum and minimum effective tension in mooring line – case2-tension 15%MBL –ballasted condition - H=30m, Period 17s

The maximum and minimum effective tension in mooring line and the maximum and minimum line displacement in X, Y and Z directions are summarized in tables 9.32 and 9.33.

The following trends and behaviours are extracted:

- The lowest observed value for minimum dynamic axial force is obtained in highest seastate with wave height 30m and wave period 17s.
- The highest value for maximum dynamic axial force is obtained in highest seastate with wave height 30m and wave period 17s.
- The lowest value for minimum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 30m and wave period 17s.

The highest value for maximum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 30m and wave period 17s.

Table 9-32 Force envelope curves for case2-tension 15%MBL –ballasted -seastate case 2

SEASTATE	FORCE ENVELOPE CURVES		
	AXIAL FORCE		
	MIN DYNAMIC	STATIC FORCE	MAX DYNAMIC
H=30m,T= 13s	-1.55E+03	2.63E+03	2.85E+03
H=30m,T=14s	-2.29E+03	2.63E+03	2.56E+03
H=30m,T= 15s	-2.75E+03	2.63E+03	2.29E+03
H=30m,T= 16s	-3.02E+03	2.63E+03	2.16E+03
H=30m,T= 17s	-3.19E+03	2.63E+03	2.20E+03

Table 9-33 Displacement envelope curves for case2-tension 15%MBL –ballasted -seastate case2

SEASTATE	DISPLACEMENT ENVELOPE CURVE					
	X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC
H=30m,T= 13s	-4.78E+00	6.64E+00	-3.16E+00	2.64E+00	-1.62E+01	1.66E+01
H=30m,T=14s	-6.75E+00	8.85E+00	-3.64E+00	2.81E+00	-1.75E+01	1.80E+01
H=30m,T= 15s	-8.43E+00	1.04E+01	-3.73E+00	2.60E+00	-1.79E+01	1.84E+01
H=30m,T= 16s	-9.83E+00	1.19E+01	-2.63E+00	2.02E+00	-1.80E+01	1.83E+01
H=30m,T= 17s	-1.10E+01	1.34E+01	-1.18E+00	1.58E+00	-1.77E+01	2.00E+01

9.4.3.2.3. Mooring line with tension 30%MBL- Regular wave H=15m, T=9-15s

For mooring line with tension 30%MBL, the maximum and minimum effective tension in regulare waves with wave height 15m and periods from 9s to 15s are shown in fgures 9.96 to 9.102.

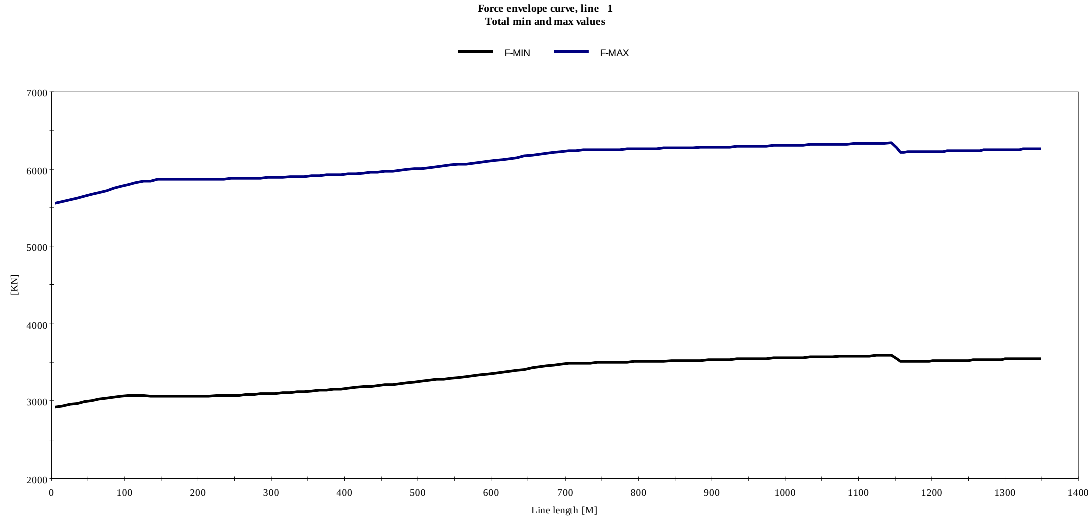

Figure 9.96 Maximum and minimum effective tension in mooring line – case2-tension 30%MBL –ballasted condition - H=15m, Period 9s

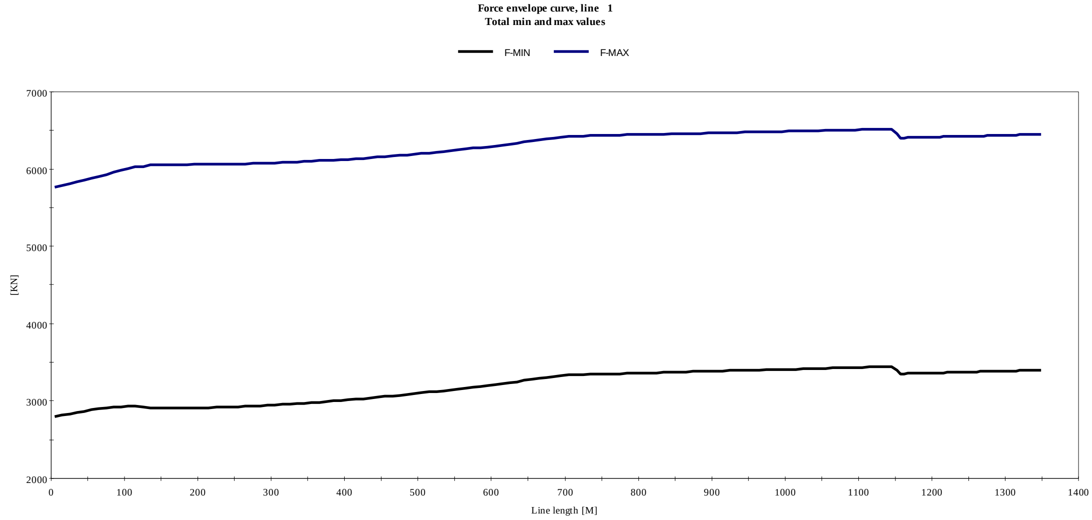

Figure 9.97 Maximum and minimum effective tension in mooring line – case2-tension 30%MBL –ballasted condition - H=15m, Period 10s

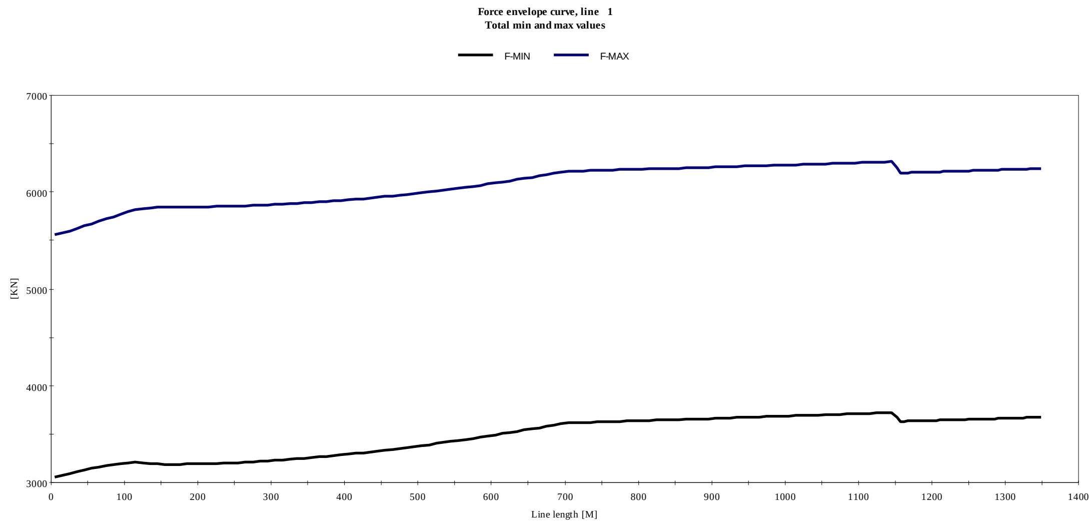

Figure 9.98 Maximum and minimum effective tension in mooring line – case2-tension 30%MBL –ballasted condition - H=15m, Period 11s

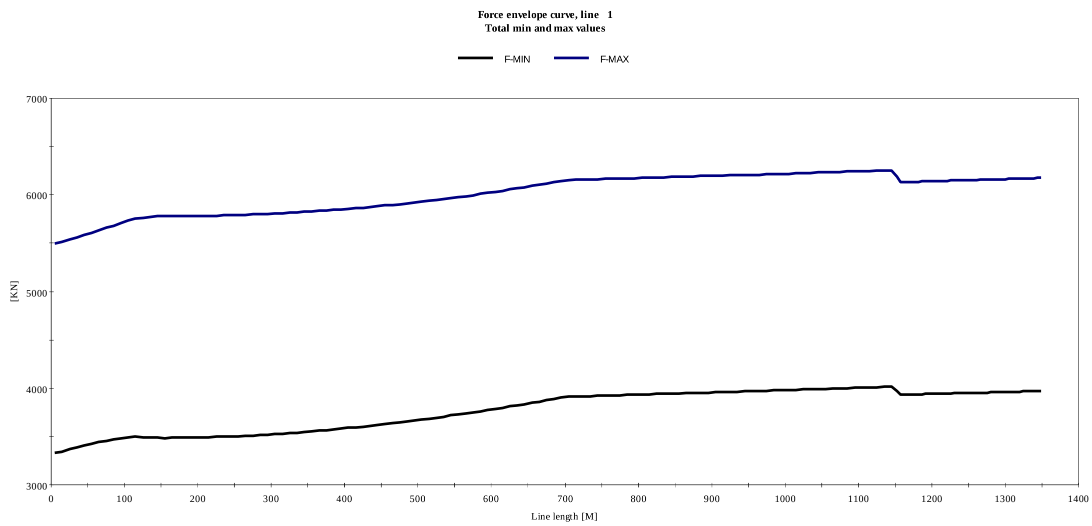

Figure 9.99 Maximum and minimum effective tension in mooring line – case2-tension 30%MBL –ballasted condition - H=15m, Period 12s

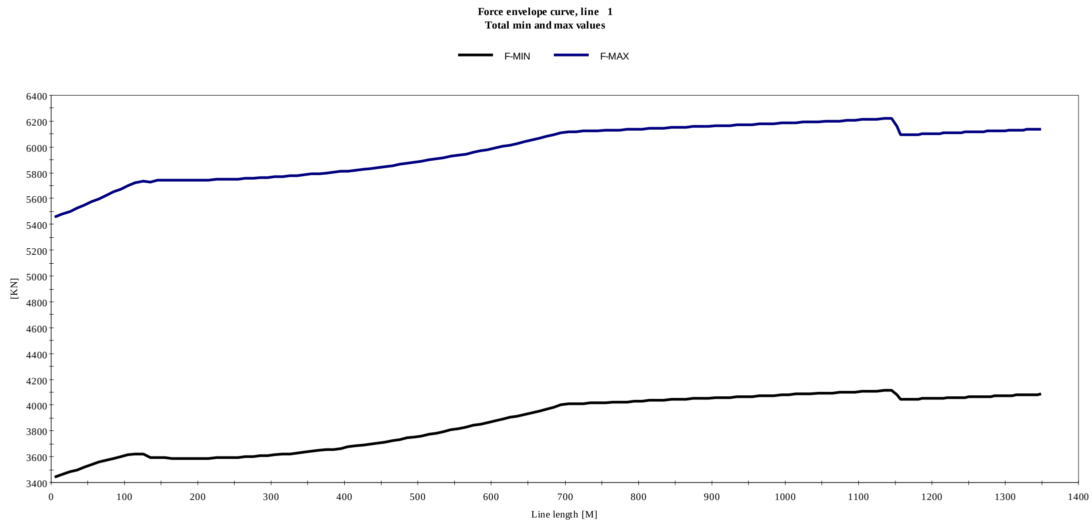

Figure 9.100 Maximum and minimum effective tension in mooring line – case2-tension 30%MBL –ballasted condition - H=15m, Period 13s

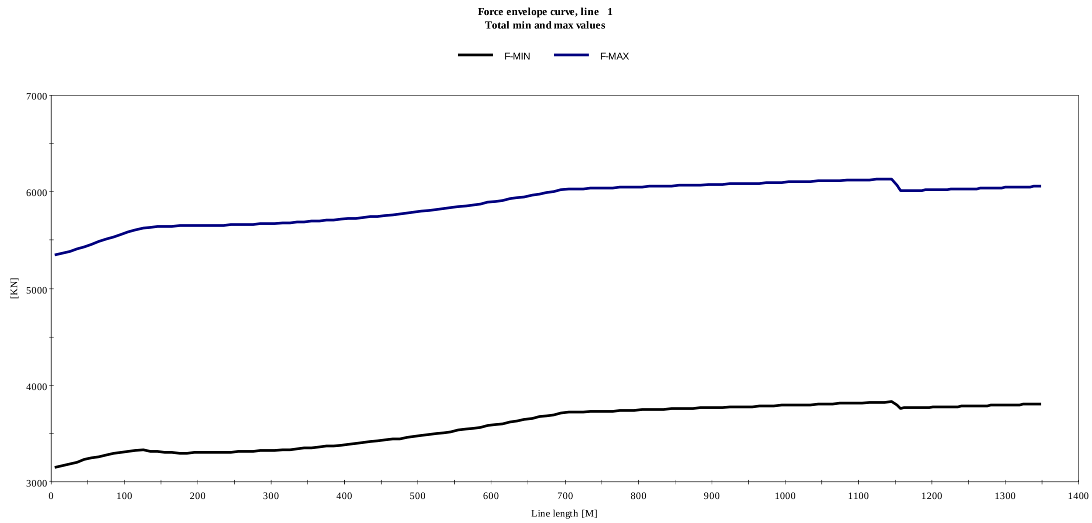

Figure 9.101 Maximum and minimum effective tension in mooring line – case2-tension 30%MBL –ballasted condition - H=15m, Period 14s

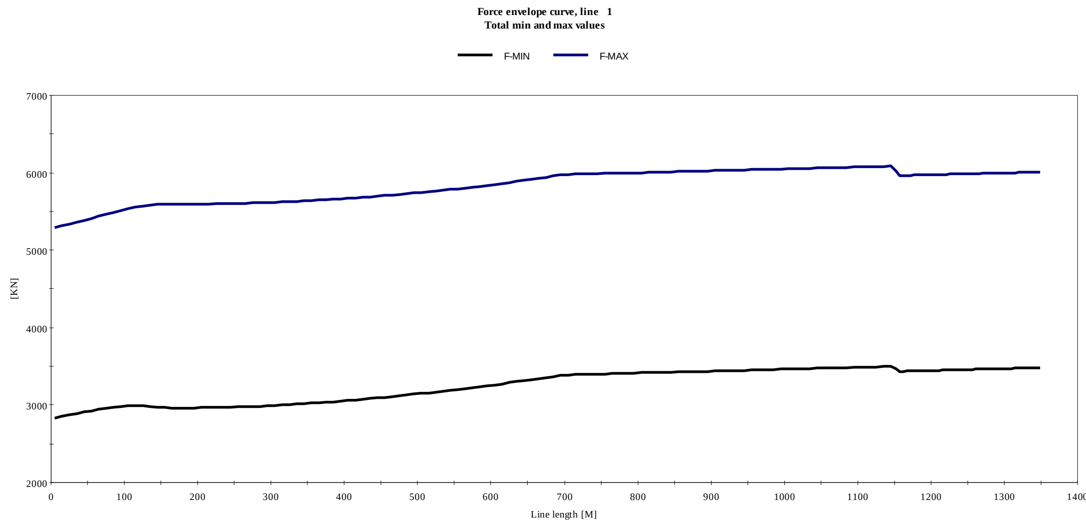

Figure 9.102 Maximum and minimum effective tension in mooring line – case2-tension 30%MBL –ballasted condition - H=15m, Period 15s

The maximum and minimum effective tension in mooring line and the maximum and minimum line displacement in X, Y and Z directions are summarized in tables 9.34 and 9.35.

The following results and behaviours are observed:

- The lowest value for minimum dynamic axial force is obtained in highest seastate with wave height 15m and wave period 15s.
- The highest value for maximum dynamic axial force is obtained in highest seastate with wave height 15m and wave period 15s.
- The lowest value for minimum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 15m and wave period 15s.
- The highest value for maximum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 15m and wave period 15s.

Table 9-34 Force envelope curves for case2-tension 30%MBL –ballasted -seastate case 1

SEASTATE	FORCE ENVELOPE CURVES		
	AXIAL FORCE		
	MIN DYNAMIC	STATIC FORCE	MAX DYNAMIC
H=15m,T= 9s	-1.38E+03	4.96E+03	1.50E+03
H=15m,T=10s	-1.53E+03	4.96E+03	1.70E+03
H=15m,T= 11s	-1.26E+03	4.96E+03	1.50E+03
H=15m,T= 12s	-9.61E+02	4.96E+03	1.43E+03
H=15m,T= 13s	-8.62E+02	4.96E+03	1.40E+03
H=15m,T= 14s	-1.15E+03	4.96E+03	1.28E+03
H=15m,T=15s	-1.49E+03	4.96E+03	1.23E+03

Table 9-35 Displacement envelope curves for case2-tension 30%MBL –ballasted -seastate case 1

SEASTATE	DISPLACEMENT ENVELOPE CURVE					
	X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC
H=15m,T= 9s	-2.06E+00	1.76E+00	-3.89E-01	4.44E-01	-3.90E+00	4.20E+00
H=15m,T=10s	-2.50E+00	2.03E+00	-6.13E-02	8.35E-02	-4.67E+00	5.05E+00
H=15m,T= 11s	-2.36E+00	2.01E+00	-6.70E-01	6.89E-01	-5.13E+00	5.16E+00
H=15m,T= 12s	-1.82E+00	1.83E+00	-1.12E+00	1.07E+00	-6.84E+00	6.90E+00
H=15m,T= 13s	-2.51E+00	2.97E+00	-1.45E+00	1.33E+00	-8.01E+00	8.15E+00
H=15m,T= 14s	-3.63E+00	4.16E+00	-1.64E+00	1.45E+00	-8.86E+00	8.98E+00
H=15m,T=15s	-4.34E+00	4.85E+00	-1.55E+00	1.31E+00	-8.87E+00	9.02E+00

9.4.3.2.4. Mooring line with tension 30%MBL- Regular wave H=30m, T=13-17s

For mooring line with tension 30%MBL, the maximum and minimum effective tension in regular waves with wave height 30m and periods from 13s to 17s are shown in figures 9.103 to 9.107.

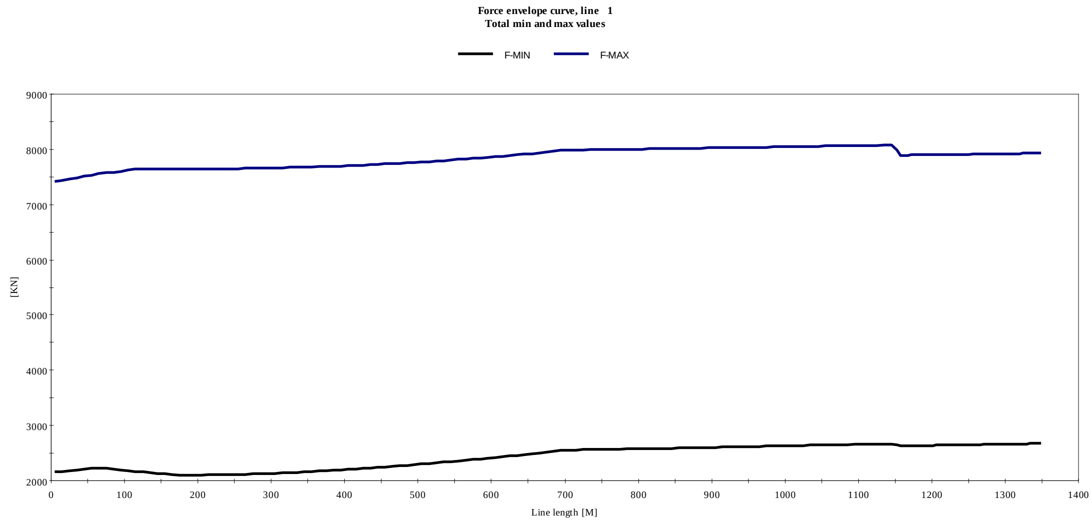

Figure 9.103 Maximum and minimum effective tension in mooring line – case2-tension 30%MBL –ballasted condition - H=30m, Period 13s

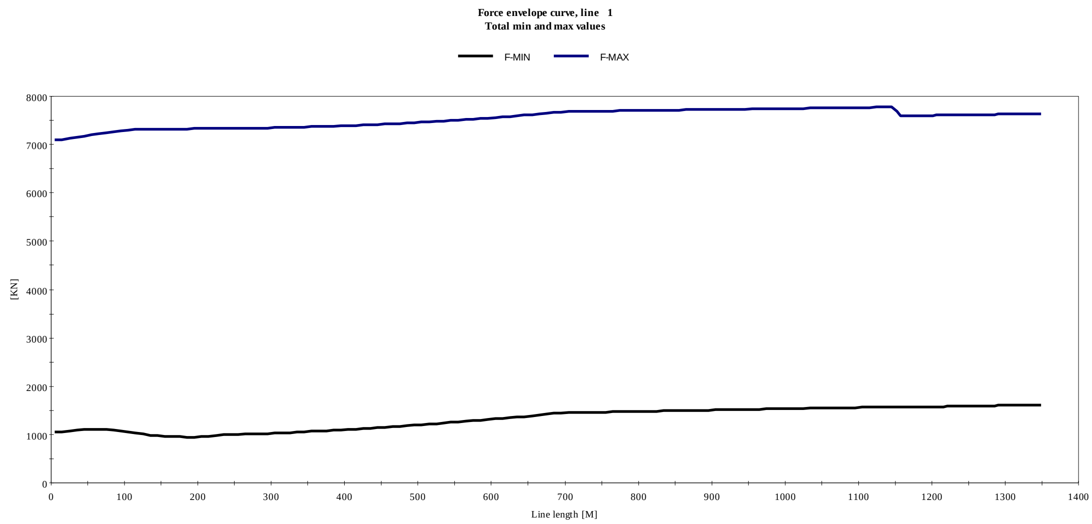

Figure 9.104 Maximum and minimum effective tension in mooring line – case2-tension 30%MBL –ballasted condition - H=30m, Period 14s

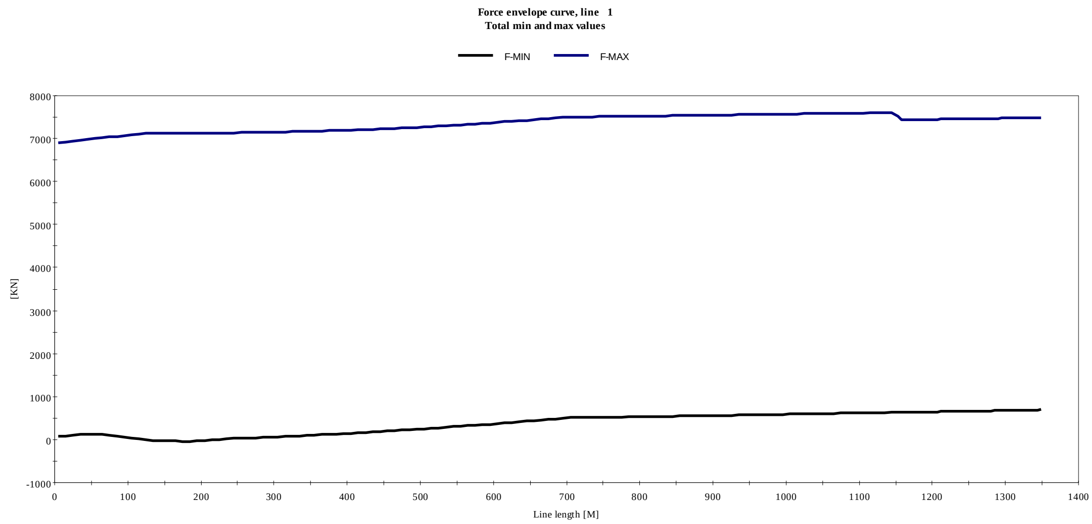

Figure 9.105 Maximum and minimum effective tension in mooring line – case2-tension 30%MBL –ballasted condition - H=30m, Period 15s

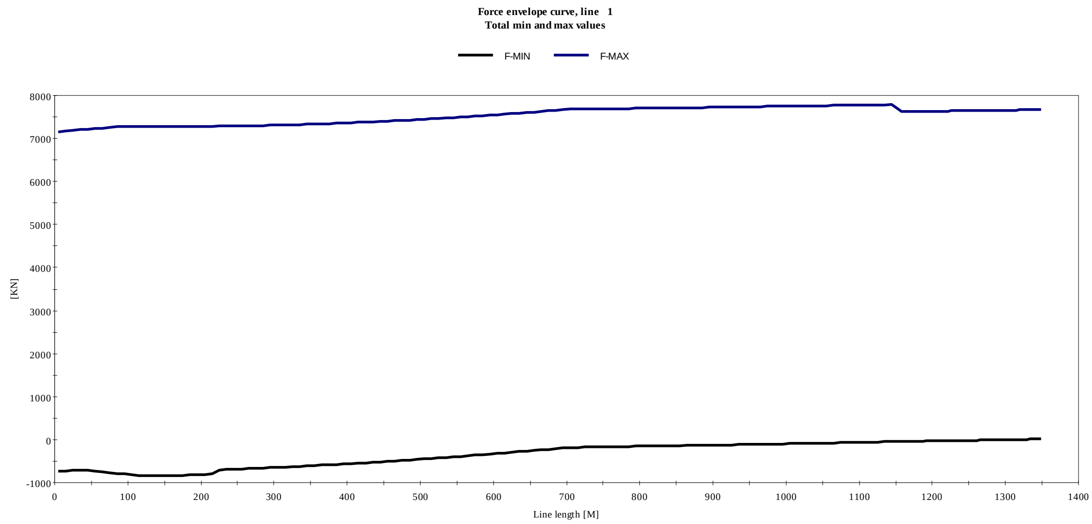

Figure 9.106 Maximum and minimum effective tension in mooring line – case2-tension 30%MBL –ballasted condition - H=30m, Period 16s

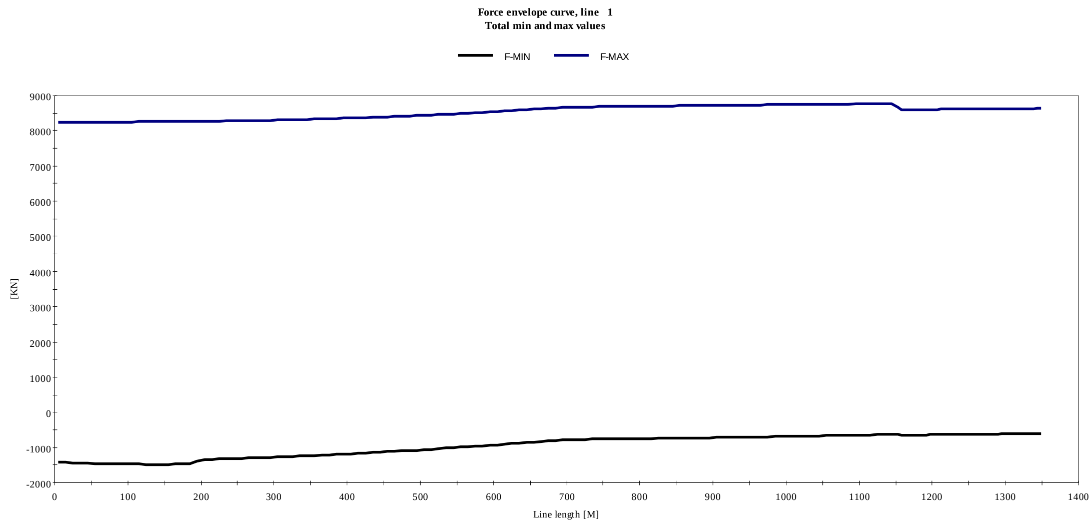

Figure 9.107 Maximum and minimum effective tension in mooring line – case2-tension 30%MBL –ballasted condition - H=30m, Period 17s

The maximum and minimum effective tension in mooring line and the maximum and minimum line displacement in X, Y and Z directions are summarized in tables 9.36 and 9.37.

The following trends and behaviours are extracted:

- The lowest observed value for minimum dynamic axial force is obtained in highest seastate with wave height 30m and wave period 17s.
- The highest value for maximum dynamic axial force is obtained in highest seastate with wave height 30m and wave period 17s.
- The lowest value for minimum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 30m and wave period 17s.

The highest value for maximum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 30m and wave period 17s.

Table 9-36 Force envelope curves for case2-tension 30%MBL –ballasted -seastate case 2

SEASTATE	FORCE ENVELOPE CURVES		
	AXIAL FORCE		
	MIN DYNAMIC	STATIC FORCE	MAX DYNAMIC
H=30m,T= 13s	-2.35E+03	4.96E+03	3.36E+03
H=30m,T=14s	-3.50E+03	4.96E+03	3.02E+03
H=30m,T= 15s	-4.49E+03	4.96E+03	2.83E+03
H=30m,T= 16s	-5.28E+03	4.96E+03	3.09E+03
H=30m,T= 17s	-5.92E+03	4.96E+03	4.16E+03

Table 9-37 Displacement envelope curves for case2-tension 30%MBL –ballasted -seastate case2

SEASTATE	DISPLACEMENT ENVELOPE CURVE					
	X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC
H=30m,T= 13s	-4.78E+00	6.64E+00	-3.16E+00	2.64E+00	-1.62E+01	1.66E+01
H=30m,T=14s	-6.75E+00	8.85E+00	-3.64E+00	2.81E+00	-1.75E+01	1.80E+01
H=30m,T= 15s	-8.43E+00	1.04E+01	-3.73E+00	2.60E+00	-1.79E+01	1.84E+01
H=30m,T= 16s	-9.83E+00	1.19E+01	-2.63E+00	2.02E+00	-1.80E+01	1.83E+01
H=30m,T= 17s	-1.10E+01	1.34E+01	-1.18E+00	1.58E+00	-1.77E+01	2.03E+01

9.4.3.2.5. Mooring line with tension 45%MBL- Regular wave H=15m, T=9-15s

For mooring line with tension 45%MBL, the maximum and minimum effective tension in regular waves with wave height 15m and periods from 9s to 15s are shown in fgures 9.108 to 9.114.

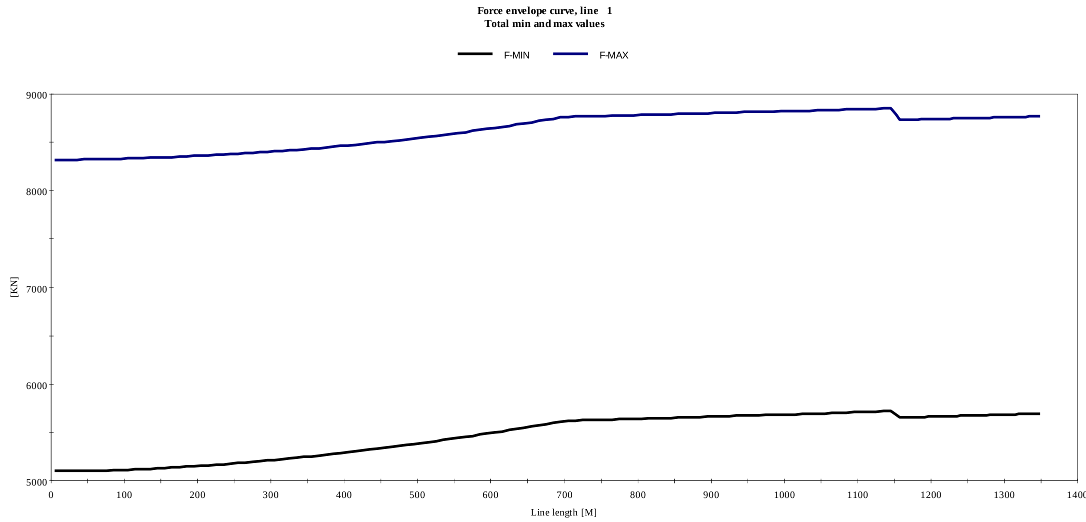

Figure 9.108 Maximum and minimum effective tension in mooring line – case2-tension 45%MBL –ballasted condition - H=15m, Period 9s

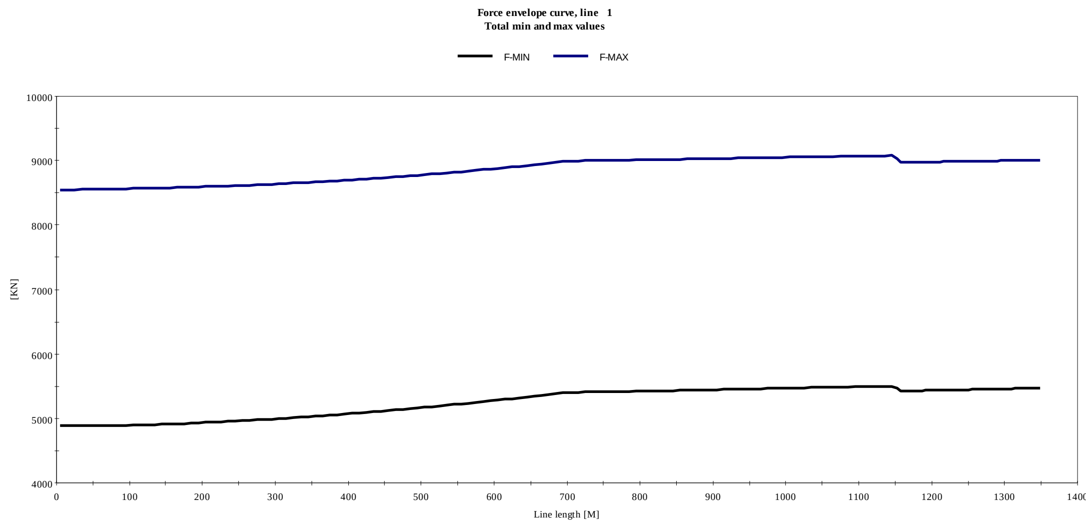

Figure 9.109 Maximum and minimum effective tension in mooring line – case2-tension 45%MBL –ballasted condition - H=15m, Period 10s

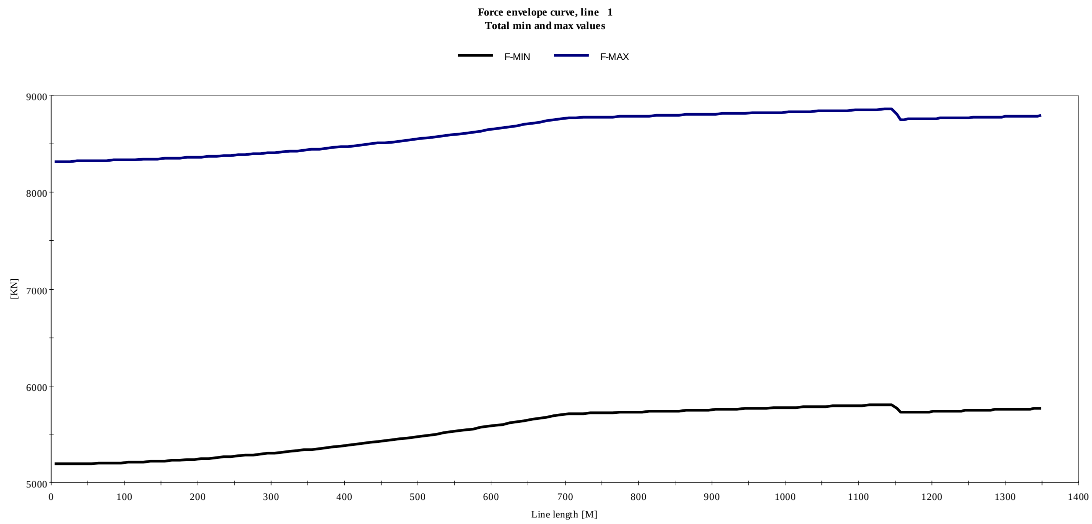

Figure 9.110 Maximum and minimum effective tension in mooring line – case2-tension 45%MBL –ballasted condition - H=15m, Period 11s

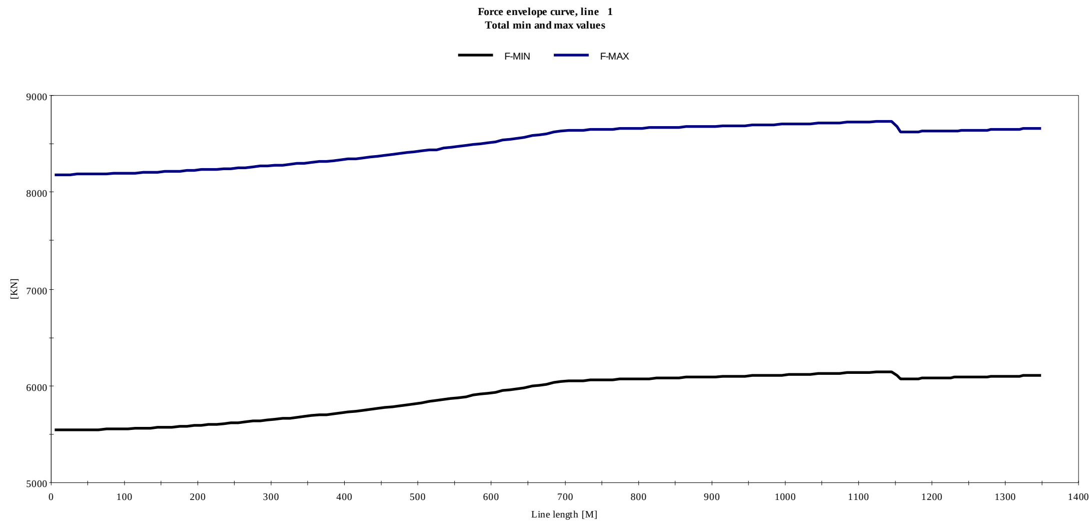

Figure 9.111 Maximum and minimum effective tension in mooring line – case2-tension 45%MBL –ballasted condition - H=15m, Period 12s

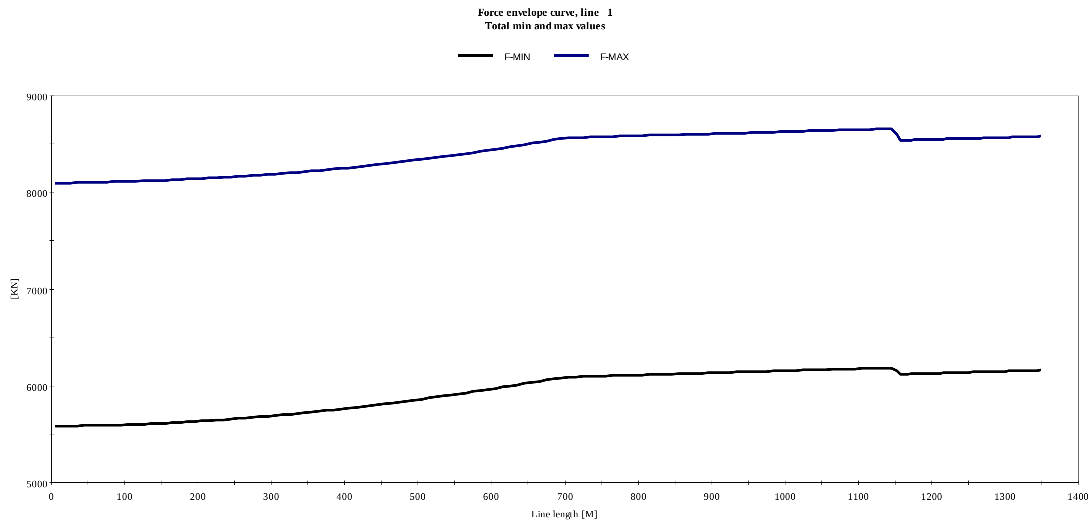

Figure 9.112 Maximum and minimum effective tension in mooring line – case2-tension 45%MBL –ballasted condition - H=15m, Period 13s

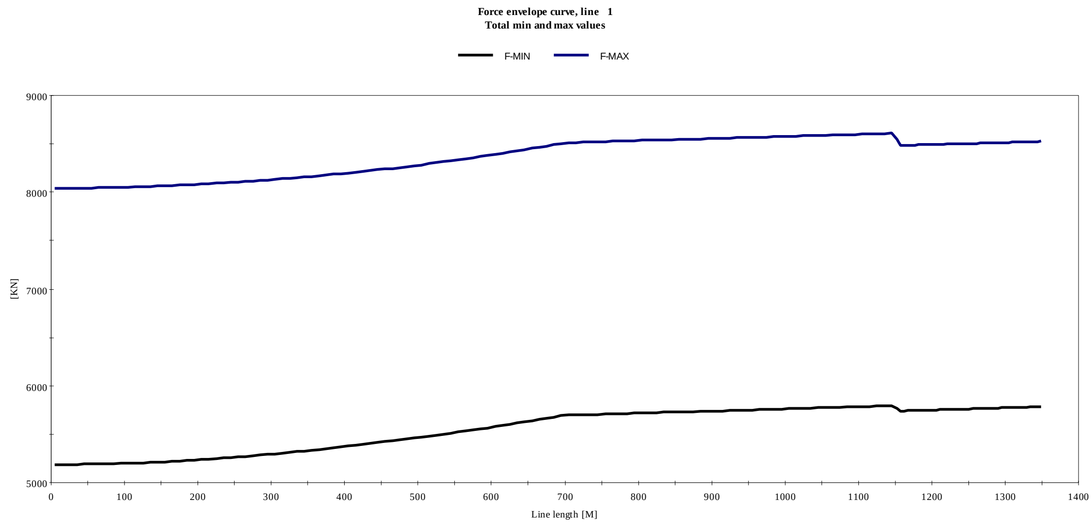

Figure 9.113 Maximum and minimum effective tension in mooring line – case2-tension 45%MBL –ballasted condition - H=15m, Period 14s

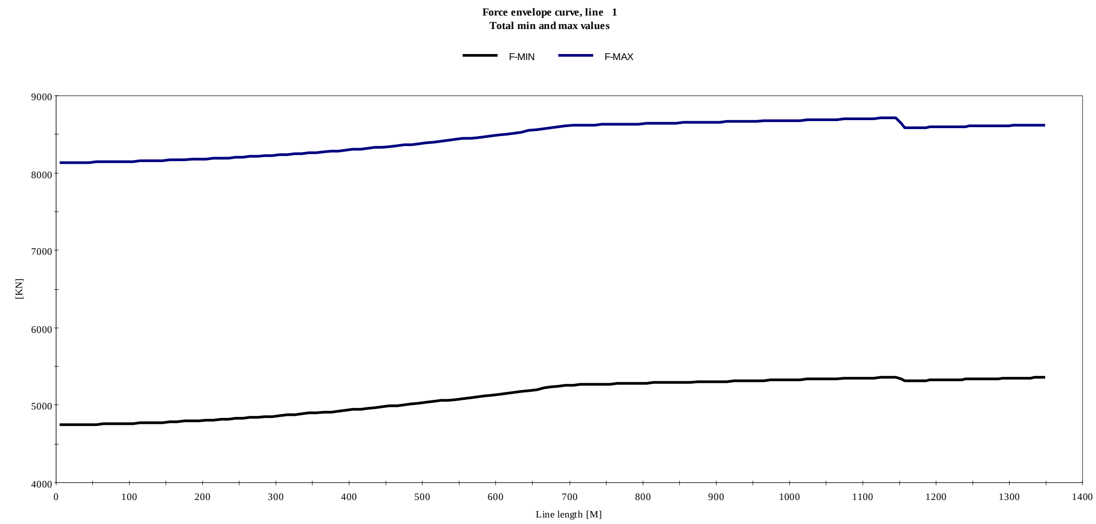

Figure 9.114 Maximum and minimum effective tension in mooring line – case2-tension 45%MBL –ballasted condition - H=15m, Period 15s

The maximum and minimum effective tension in mooring line and the maximum and minimum line displacement in X, Y and Z directions are summarized in tables 9.38 and 9.39.

The following results and behaviours are observed:

- The lowest value for minimum dynamic axial force is obtained in highest seastate with wave height 15m and wave period 15s.
- The highest value for maximum dynamic axial force is obtained in highest seastate with wave height 15m and wave period 15s.
- The lowest value for minimum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 15m and wave period 15s.

The highest value for maximum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 15m and wave period 15s.

Table 9-38 Force envelope curves for case2-tension 45%MBL –ballasted -seastate case 1

SEASTATE	FORCE ENVELOPE CURVES		
	AXIAL FORCE		
	MIN DYNAMIC	STATIC FORCE	MAX DYNAMIC
H=15m,T= 9s	-1.57E+03	7.26E+03	1.65E+03
H=15m,T=10s	-1.79E+03	7.26E+03	1.88E+03
H=15m,T= 11s	-1.48E+03	7.26E+03	1.65E+03
H=15m,T= 12s	-1.13E+03	7.26E+03	1.51E+03
H=15m,T= 13s	-1.09E+03	7.26E+03	1.43E+03
H=15m,T= 14s	-1.49E+03	7.26E+03	1.37E+03
H=15m,T=15s	-1.92E+03	7.26E+03	1.46E+03

Table 9-39 Displacement envelope curves for case2-tension 45%MBL –ballasted -seastate case 1

SEASTATE	DISPLACEMENT ENVELOPE CURVE					
	X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC
H=15m,T= 9s	-1.22E+00	1.15E+00	-4.77E-01	4.67E-01	-3.24E+00	3.38E+00
H=15m,T=10s	-1.52E+00	1.39E+00	-6.13E-02	8.35E-02	-4.14E+00	4.18E+00
H=15m,T= 11s	-1.53E+00	1.45E+00	-6.91E-01	7.08E-01	-5.13E+00	5.16E+00
H=15m,T= 12s	-1.51E+00	1.83E+00	-1.12E+00	1.07E+00	-6.84E+00	6.90E+00
H=15m,T= 13s	-2.61E+00	3.08E+00	-1.47E+00	1.35E+00	-8.19E+00	8.29E+00
H=15m,T= 14s	-3.63E+00	4.16E+00	-1.64E+00	1.45E+00	-8.86E+00	8.98E+00
H=15m,T=15s	-4.46E+00	4.97E+00	-1.58E+00	1.32E+00	-9.05E+00	9.17E+00

9.4.3.2.6. Mooring line with tension 45%MBL- Regular wave H=30m, T=13-17s

For mooring line with tension 45%MBL, the maximum and minimum effective tension in regulare waves with wave height 30m and periods from 13s to 17s are shown in fgures 9.115 to 9.119.

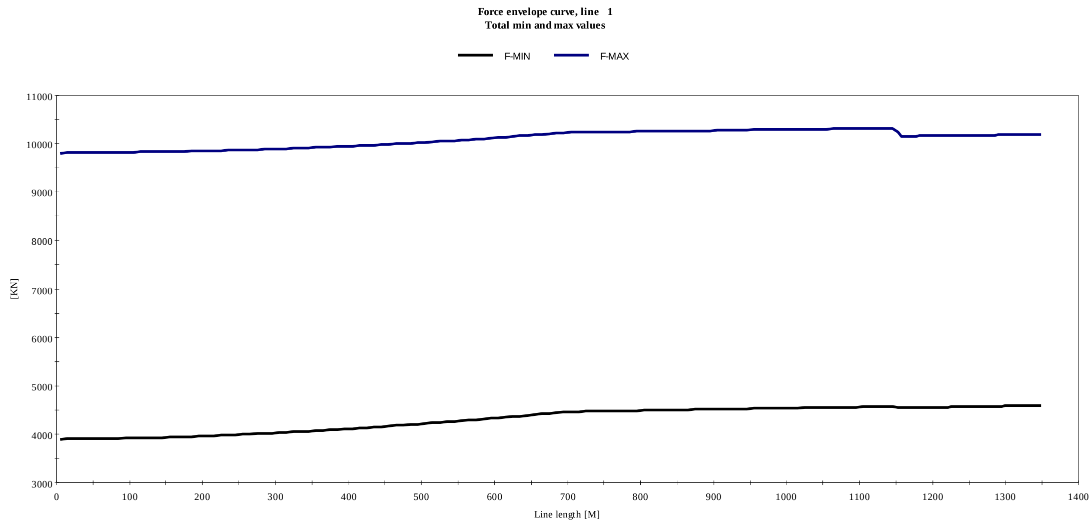

Figure 9.115 Maximum and minimum effective tension in mooring line – case2-tension 45%MBL –ballasted condition - H=30m, Period 13s

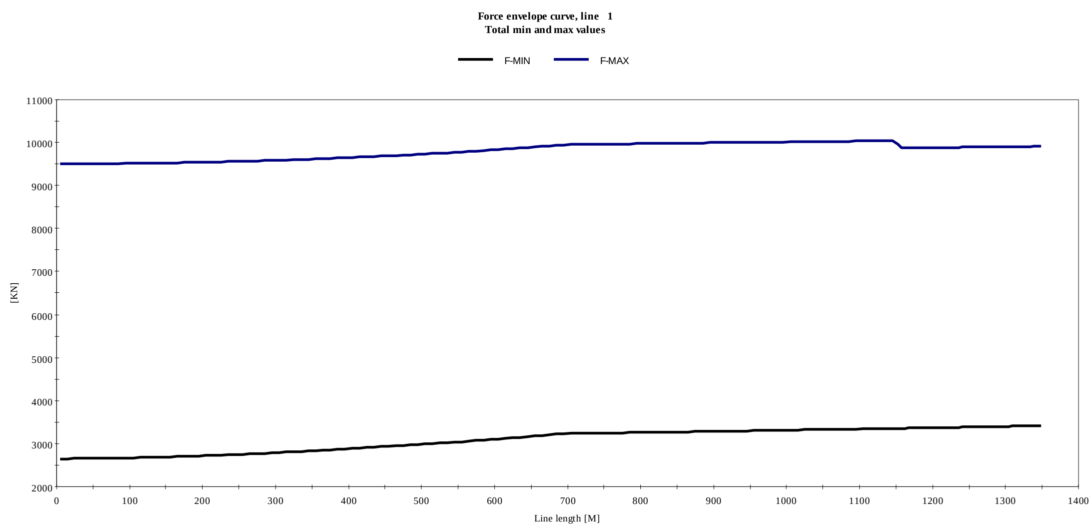

Figure 9.116 Maximum and minimum effective tension in mooring line – case2-tension 45%MBL –ballasted condition - H=30m, Period 14s

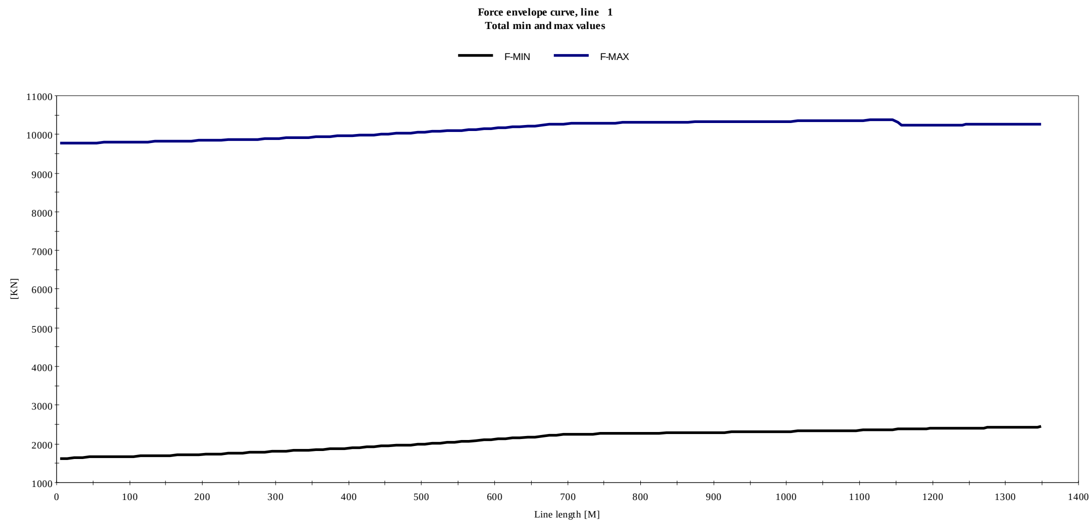

Figure 9.117 Maximum and minimum effective tension in mooring line – case2-tension 45%MBL –ballasted condition - H=30m, Period 15s

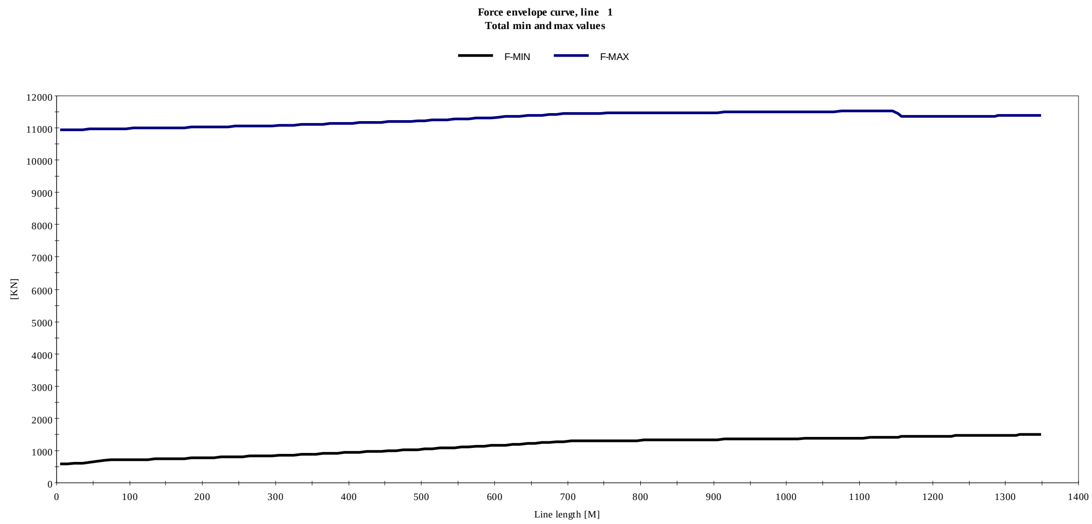

Figure 9.118 Maximum and minimum effective tension in mooring line – case2-tension 45%MBL –ballasted condition - H=30m, Period 16s

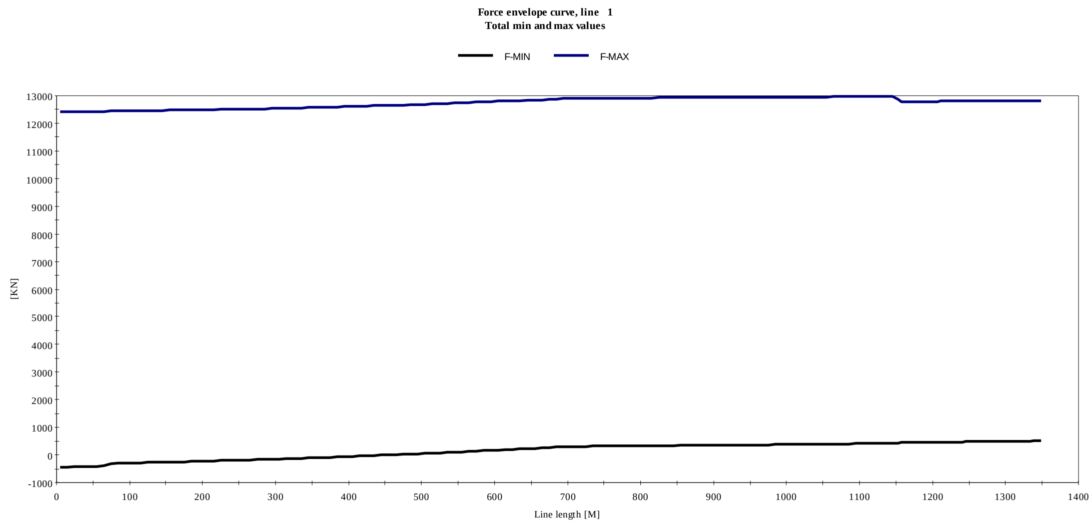

Figure 9.119 Maximum and minimum effective tension in mooring line – case2-tension 45%MBL –ballasted condition - H=30m, Period 17s

The maximum and minimum effective tension in mooring line and the maximum and minimum line displacement in X, Y and Z directions are summarized in tables 9.40 and 9.41.
The following trends and behaviours are extracted:

- The lowest observed value for minimum dynamic axial force is obtained in highest seastate with wave height 30m and wave period 17s.
- The highest value for maximum dynamic axial force is obtained in highest seastate with wave height 30m and wave period 17s.
- The lowest value for minimum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 30m and wave period 17s.
- The highest value for maximum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 30m and wave period 17s.

Table 9-40 Force envelope curves for case2-tension 45%MBL –ballasted -seastate case 2

SEASTATE	FORCE ENVELOPE CURVES		
	AXIAL FORCE		
	MIN DYNAMIC	STATIC FORCE	MAX DYNAMIC
H=30m,T= 13s	-2.78E+03	7.26E+03	3.14E+03
H=30m,T=14s	-4.02E+03	7.26E+03	2.83E+03
H=30m,T= 15s	-5.05E+03	7.26E+03	3.12E+03
H=30m,T= 16s	-6.09E+03	7.26E+03	4.31E+03
H=30m,T= 17s	-7.12E+03	7.26E+03	5.77E+03

Table 9-41 Displacement envelope curves for case2-tension 45%MBL –ballasted -seastate case2

SEASTATE	DISPLACEMENT ENVELOPE CURVE					
	X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC
H=30m,T= 13s	-4.78E+00	6.64E+00	-3.16E+00	2.64E+00	-1.62E+01	1.66E+01
H=30m,T=14s	-6.75E+00	8.85E+00	-3.64E+00	2.81E+00	-1.75E+01	1.80E+01
H=30m,T= 15s	-8.43E+00	1.04E+01	-3.73E+00	2.60E+00	-1.79E+01	1.84E+01
H=30m,T= 16s	-9.83E+00	1.19E+01	-2.63E+00	2.02E+00	-1.80E+01	1.83E+01
H=30m,T= 17s	-1.10E+01	1.34E+01	-1.18E+00	1.58E+00	-1.77E+01	1.93E+01

9.4.4. Case 2- loaded condition

9.4.4.1 Static analysis

Static analysis was carried out for mooring line when the tension on line is 15%, 30% and 45% of MBL (minimum breaking load), two sets of regular waves with different wave period and wave heights applied on system and vessel is in ballasted condition. Mooring line shapes in XZ plane are shown in figures 9.120., 9.121., 9.122. With comparison between these figures, when the tension on the mooring line increased the seafloor interaction will decreased.

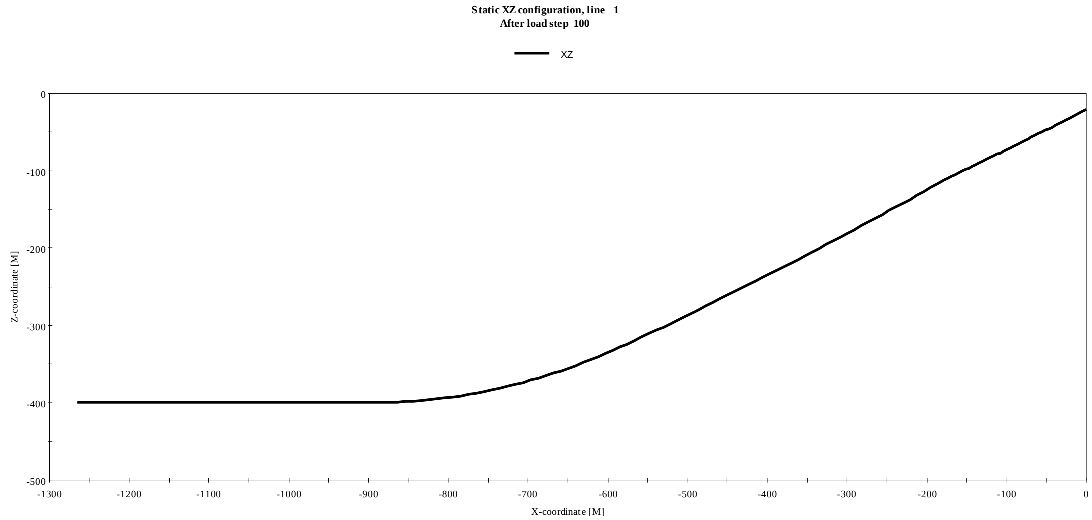

Figure 9.120 Mooring line shape in XZ plane with tension 15% MBL-case2-loaded

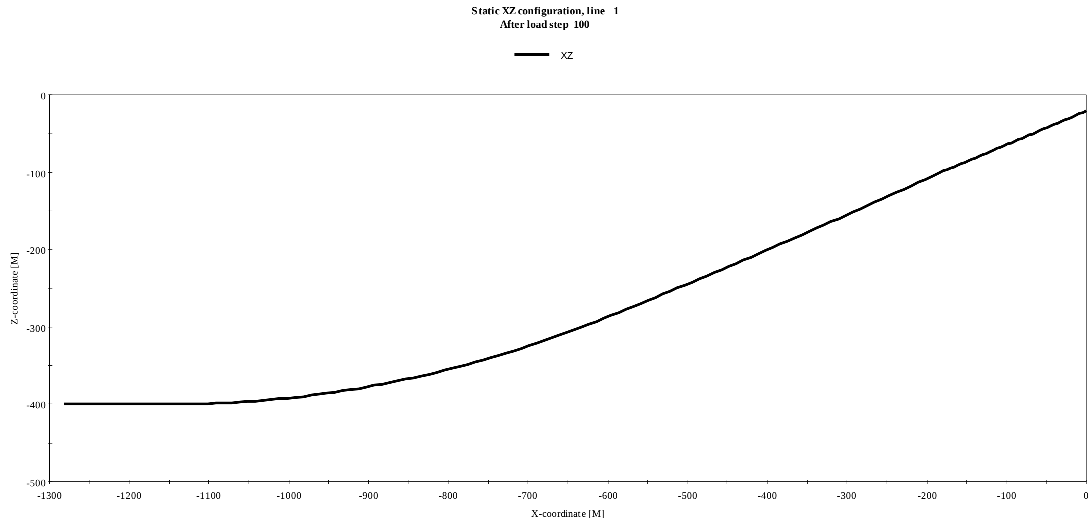

Figure 9.121 Mooring line shape in XZ plane with tension 30% MBL-case2-loaded

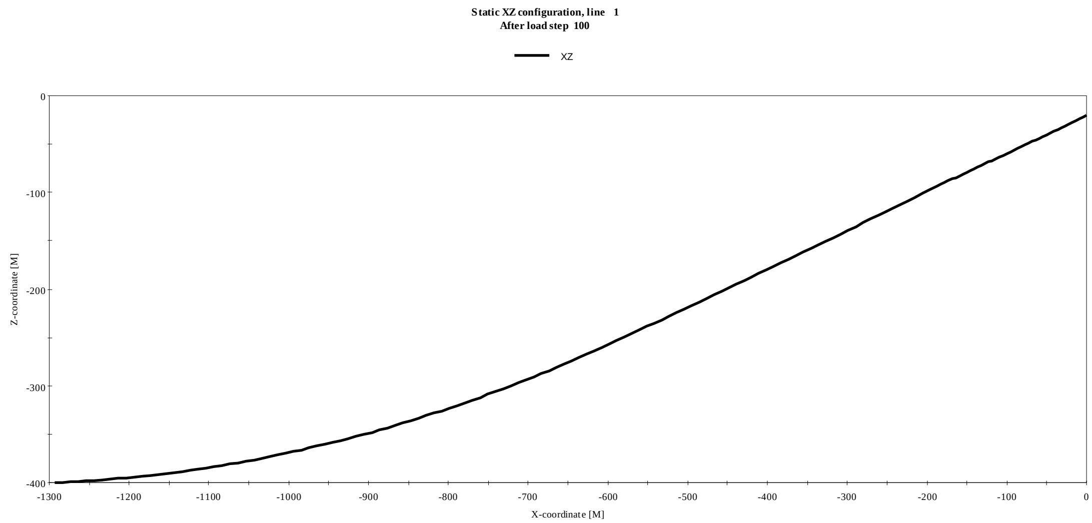

Figure 9.122 Mooring line shape in XZ plane with tension 45% MBL-case2-loaded

9.4.4.2 Dynamic analysis

The maximum and minimum effective tension of the mooring line for three line configuration when the tension applied on line is 15%, 30% and 45% are shown below. Also, in this section all line displacements are summerized in following tables.

9.4.4.2.1. Mooring line with tension 15%MBL- Regular wave H=15m, T=9-15s

For mooring line with tension 15%MBL, the maximum and minimum effective tension in regulare waves with wave height 15m and periods from 9s to 15s are shown in fgures 9.123 to 9.129.

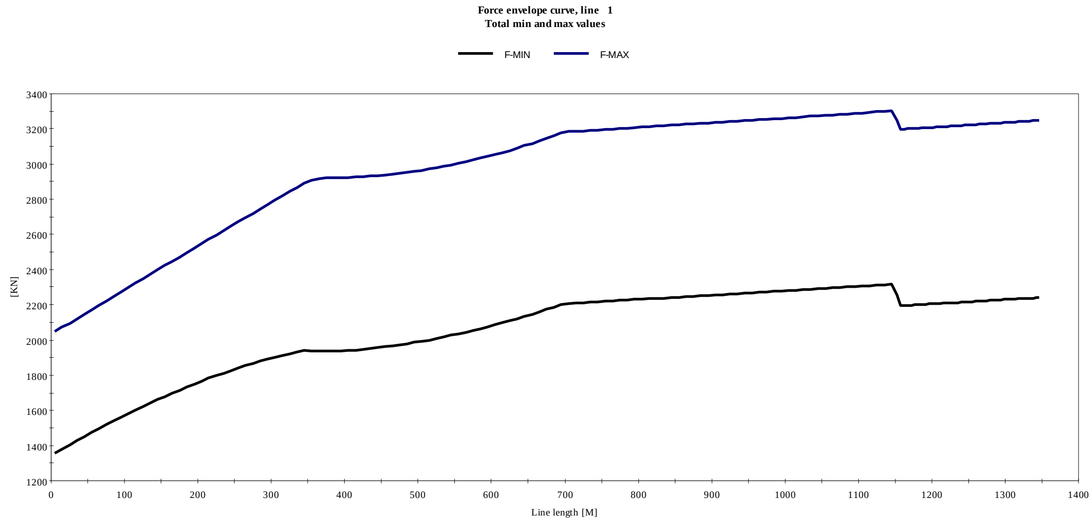

Figure 9.123 Maximum and minimum effective tension in mooring line – case2-tension 15%MBL –loaded condition - H=15m, Period 9s

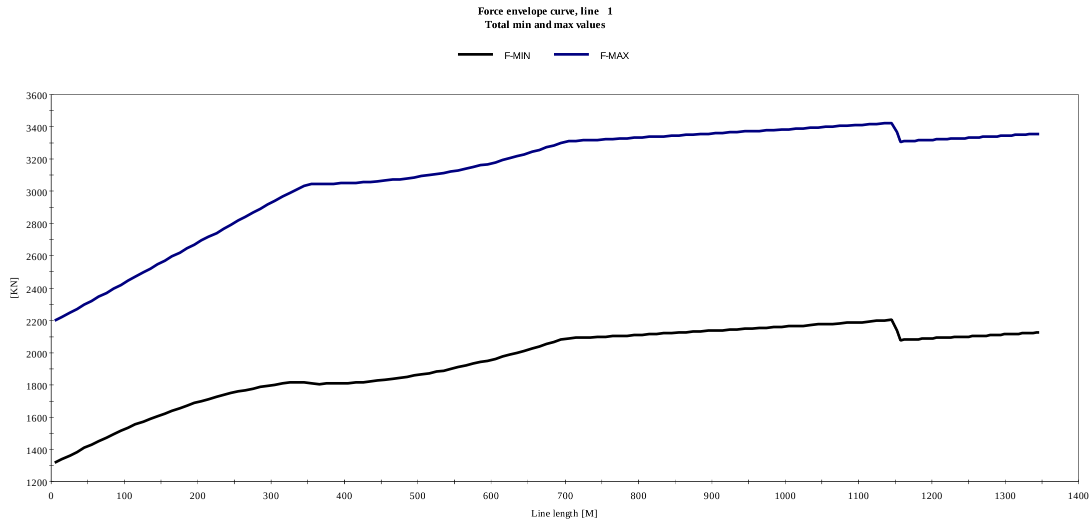

Figure 9.124 Maximum and minimum effective tension in mooring line – case2-tension 15%MBL –loaded condition - H=15m, Period 10s

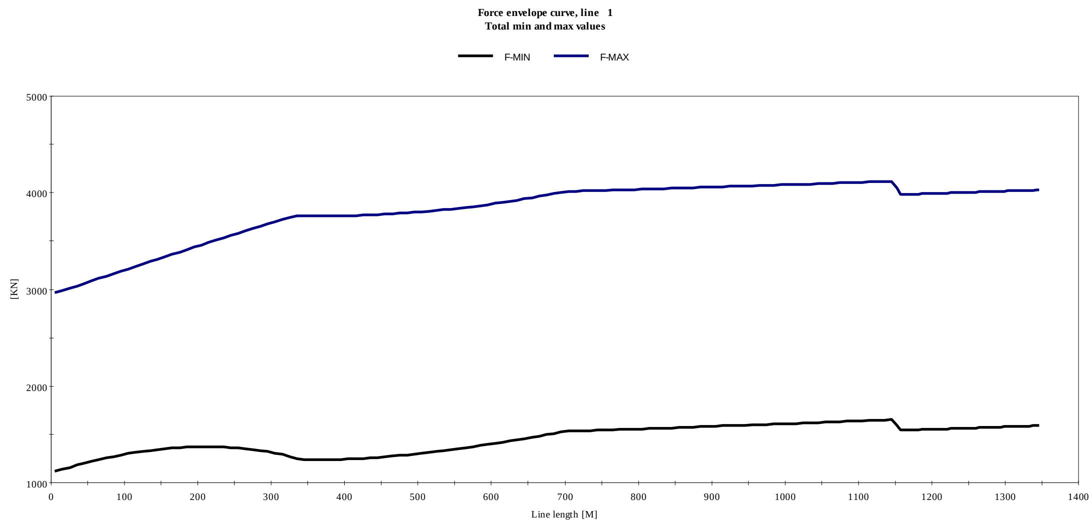

Figure 9.125 Maximum and minimum effective tension in mooring line – case2-tension 15%MBL –loaded condition - H=15m, Period 11s

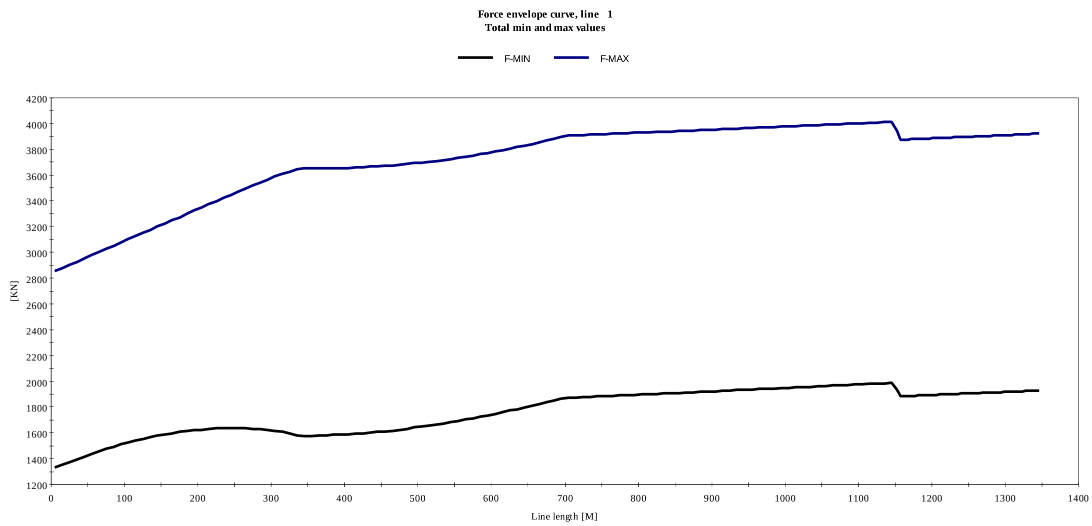

Figure 9.126 Maximum and minimum effective tension in mooring line – case2-tension 15%MBL –loaded condition - H=15m, Period 12s

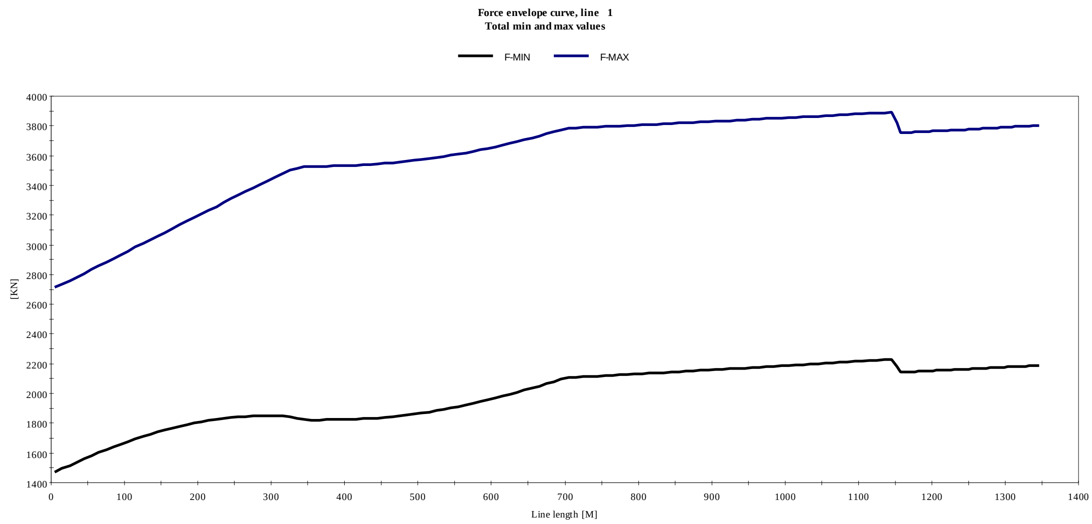

Figure 9.127 Maximum and minimum effective tension in mooring line – case2-tension 15%MBL –loaded condition - H=15m, Period 13s

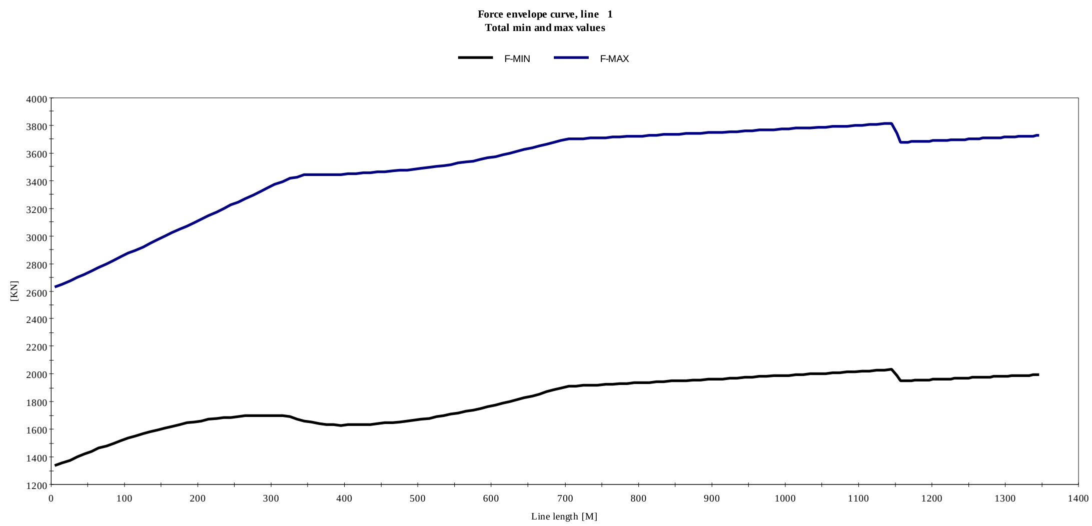

Figure 9.128 Maximum and minimum effective tension in mooring line – case2-tension 15%MBL –loaded condition - H=15m, Period 14s

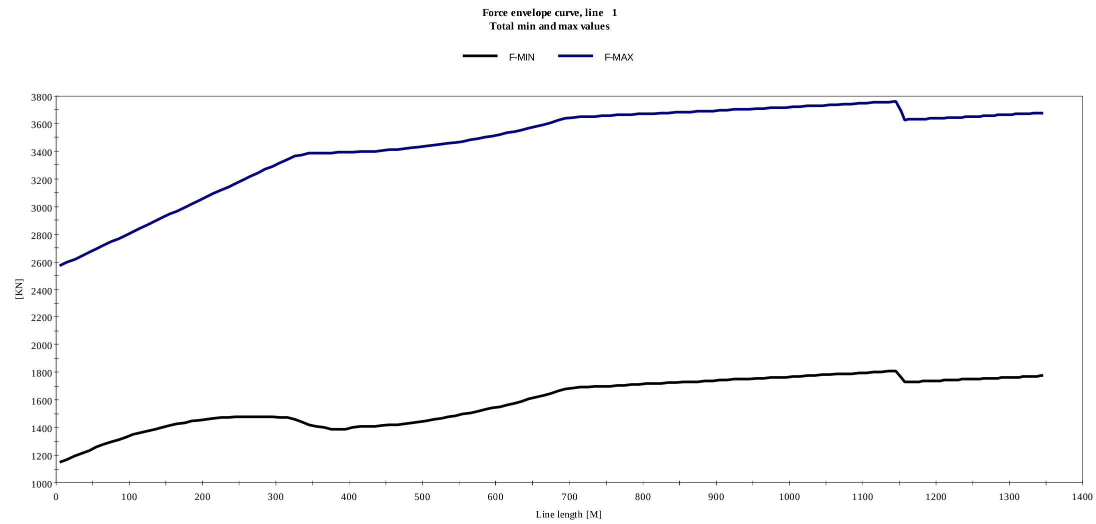

Figure 9.129 Maximum and minimum effective tension in mooring line – case2-tension 15%MBL –loaded condition - H=15m, Period 15s

The maximum and minimum effective tension in mooring line and the maximum and minimum line displacement in X, Y and Z directions are summarized in tables 9.42 and 9.43.

The following results and behaviours are observed:

- The lowest value for minimum dynamic axial force is obtained in highest seastate with wave height 15m and wave period 15s.
- The highest value for maximum dynamic axial force is obtained in highest seastate with wave height 15m and wave period 15s.
- The lowest value for minimum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 15m and wave period 15s.
- The highest value for maximum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 15m and wave period 15s.

Table 9-42 Force envelope curves for case2-tension 15%MBL –loaded -seastate case 1

SEASTATE	FORCE ENVELOPE CURVES		
	AXIAL FORCE		
	MIN DYNAMIC	STATIC FORCE	MAX DYNAMIC
H=15m,T= 9s	-5.54E+02	2.86E+03	4.92E+02
H=15m,T=10s	-6.70E+02	2.86E+03	6.41E+02
H=15m,T= 11s	-1.23E+03	2.86E+03	1.41E+03
H=15m,T= 12s	-8.87E+02	2.86E+03	1.30E+03
H=15m,T= 13s	-6.47E+02	2.86E+03	1.16E+03
H=15m,T= 14s	-8.43E+02	2.86E+03	1.07E+03
H=15m,T=15s	-1.08E+03	2.86E+03	1.02E+03

Table 9-43 Displacement envelope curves for case2-tension 15%MBL –loaded -seastate case 1

SEASTATE	DISPLACEMENT ENVELOPE CURVE					
	X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC
H=15m,T= 9s	-1.66E+00	1.69E+00	-6.09E-01	5.56E-01	-3.05E+00	3.23E+00
H=15m,T=10s	-2.39E+00	2.28E+00	-3.13E-01	3.11E-01	-4.08E+00	4.22E+00
H=15m,T= 11s	-4.41E+00	3.46E+00	-5.54E-01	5.52E-01	-5.88E+00	7.11E+00
H=15m,T= 12s	-3.66E+00	3.08E+00	-1.08E+00	1.06E+00	-6.79E+00	6.99E+00
H=15m,T= 13s	-2.43E+00	2.54E+00	-1.55E+00	1.50E+00	-7.86E+00	7.95E+00
H=15m,T= 14s	-3.19E+00	3.65E+00	-1.82E+00	1.74E+00	-8.47E+00	8.59E+00
H=15m,T=15s	-4.07E+00	4.55E+00	-1.95E+00	1.85E+00	-8.73E+00	8.86E+00

9.4.4.2.2. Mooring line with tension 15%MBL- Regular wave H=30m, T=13-17s

For mooring line with tension 15%MBL, the maximum and minimum effective tension in regulare waves with wave height 30m and periods from 13s to 17s are shown in fgures 9.130 to 9.134.

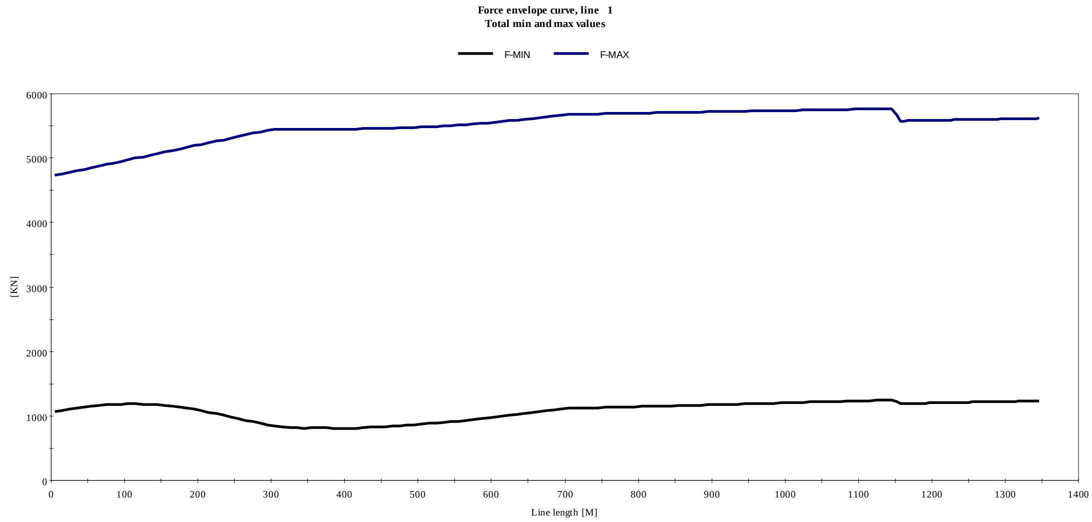

Figure 9.130 Maximum and minimum effective tension in mooring line – case2-tension 15%MBL –loaded condition - H=30m, Period 13s

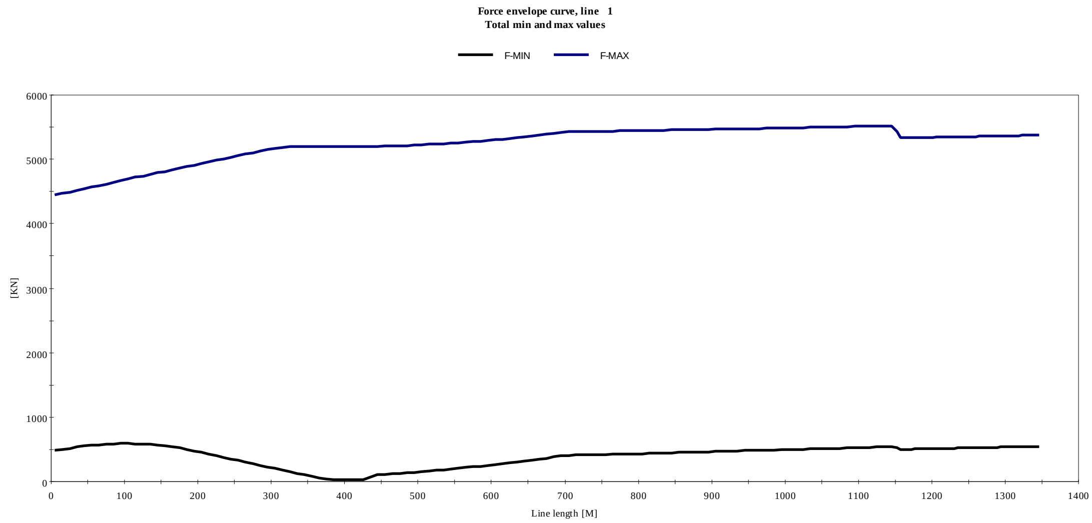

Figure 9.131 Maximum and minimum effective tension in mooring line – case2-tension 15%MBL –loaded condition - H=30m, Period 14s

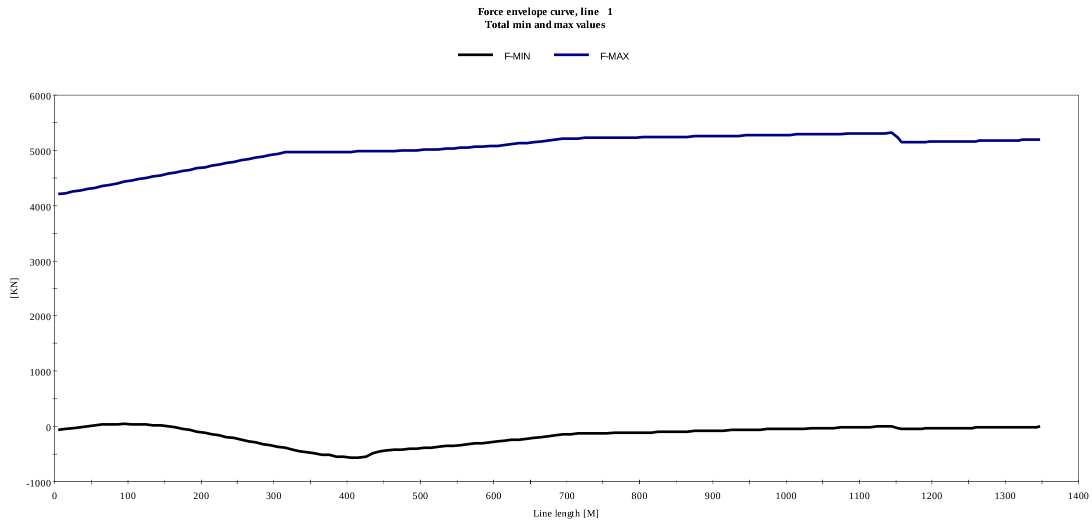

Figure 9.132 Maximum and minimum effective tension in mooring line – case2-tension 15%MBL –loaded condition -H=30m, Period 15s

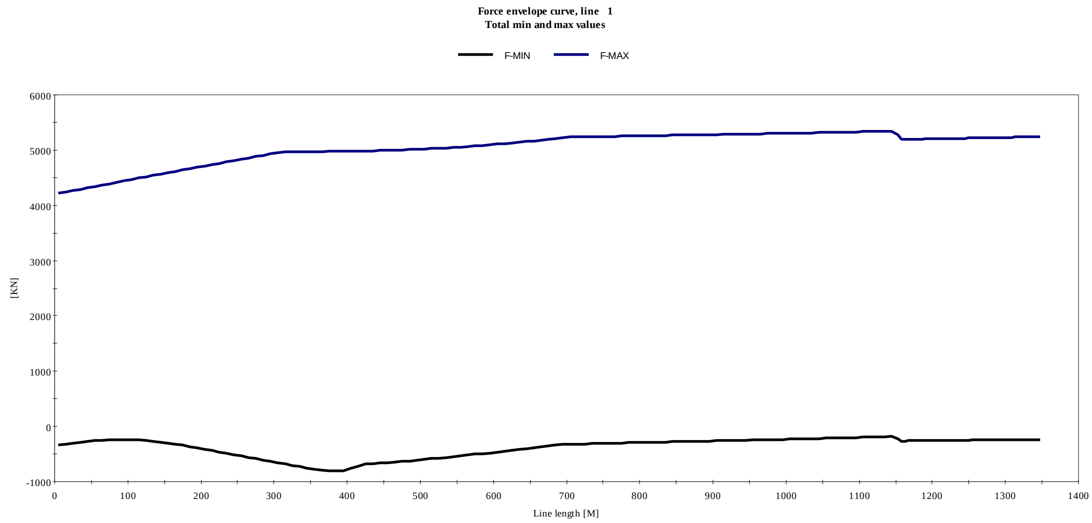

Figure 9.133 Maximum and minimum effective tension in mooring line – case2-tension 15%MBL –loaded condition -H=30m, Period 16s

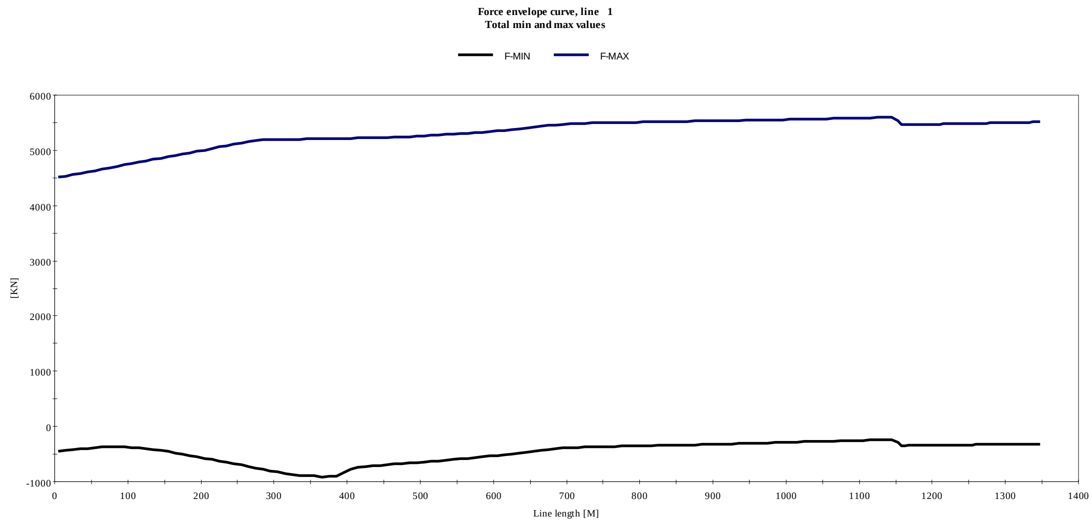

Figure 9.134 Maximum and minimum effective tension in mooring line – case2-tension 15%MBL –loaded condition - H=30m, Period 17s

The maximum and minimum effective tension in mooring line and the maximum and minimum line displacement in X, Y and Z directions are summarized in tables 9.44 and 9.45.

The following trends and behaviours are extracted:

- The lowest observed value for minimum dynamic axial force is obtained in highest seastate with wave height 30m and wave period 17s.
- The highest value for maximum dynamic axial force is obtained in highest seastate with wave height 30m and wave period 17s.
- The lowest value for minimum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 30m and wave period 17s.
- The highest value for maximum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 30m and wave period 17s.

Table 9-44 Force envelope curves for case2-tension 15%MBL –loaded -seastate case 2

SEASTATE	FORCE ENVELOPE CURVES		
	AXIAL FORCE		
	MIN DYNAMIC	STATIC FORCE	MAX DYNAMIC
H=30m,T= 13s	-1.67E+03	2.86E+03	3.18E+03
H=30m,T=14s	-2.45E+03	2.86E+03	2.89E+03
H=30m,T= 15s	-3.03E+03	2.86E+03	2.65E+03
H=30m,T= 16s	-3.27E+03	2.86E+03	2.67E+03
H=30m,T= 17s	-3.38E+03	2.86E+03	2.96E+03

Table 9-45 Displacement envelope curves for case2-tension 15%MBL –loaded -seastate case2

SEASTATE	DISPLACEMENT ENVELOPE CURVE					
	X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC
H=30m,T= 13s	-4.78E+00	6.64E+00	-3.16E+00	2.64E+00	-1.62E+01	1.66E+01
H=30m,T=14s	-6.75E+00	8.85E+00	-3.74E+00	3.43E+00	-1.75E+01	1.80E+01
H=30m,T= 15s	-7.66E+00	9.57E+00	-4.03E+00	3.65E+00	-1.73E+01	1.78E+01
H=30m,T= 16s	-9.09E+00	1.09E+01	-4.23E+00	3.76E+00	-1.75E+01	1.80E+01
H=30m,T= 17s	-1.03E+01	1.18E+01	-4.36E+00	3.76E+00	-1.74E+01	2.02E+01

9.4.4.2.3. Mooring line with tension 30%MBL- Regular wave H=15m, T=9-15s

For mooring line with tension 30%MBL, the maximum and minimum effective tension in regulare waves with wave height 15m and periods from 9s to 15s are shown in fgures 9.135 to 9.141.

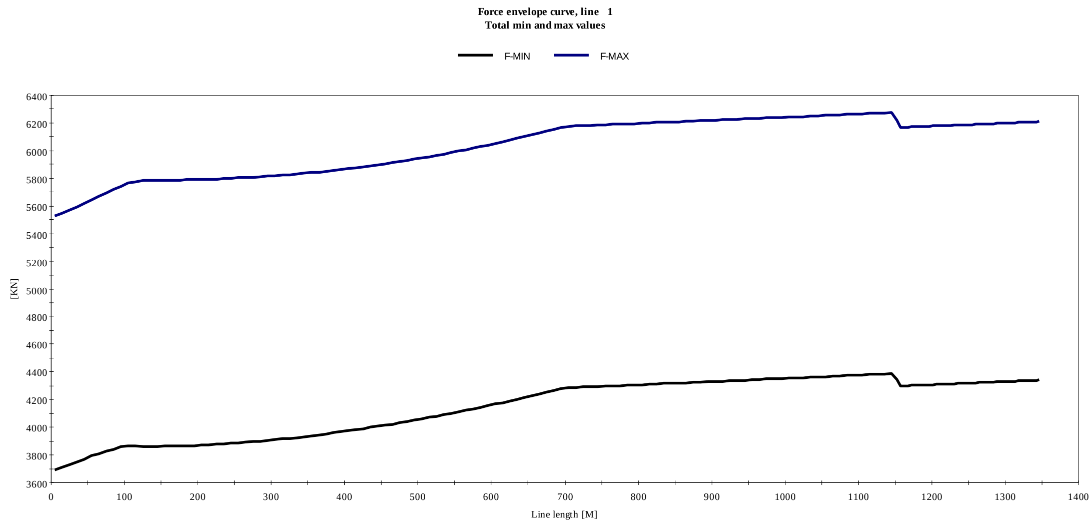

Figure 9.135 Maximum and minimum effective tension in mooring line – case2-tension 30%MBL –loaded condition - H=15m, Period 9s

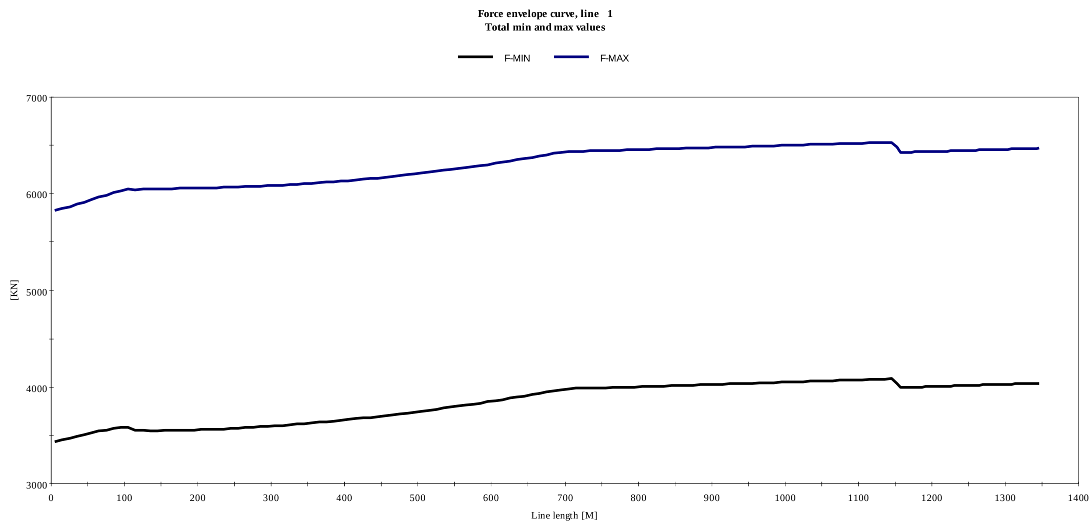

Figure 9.136 Maximum and minimum effective tension in mooring line – case2-tension 30%MBL –loaded condition - H=15m, Period 10s

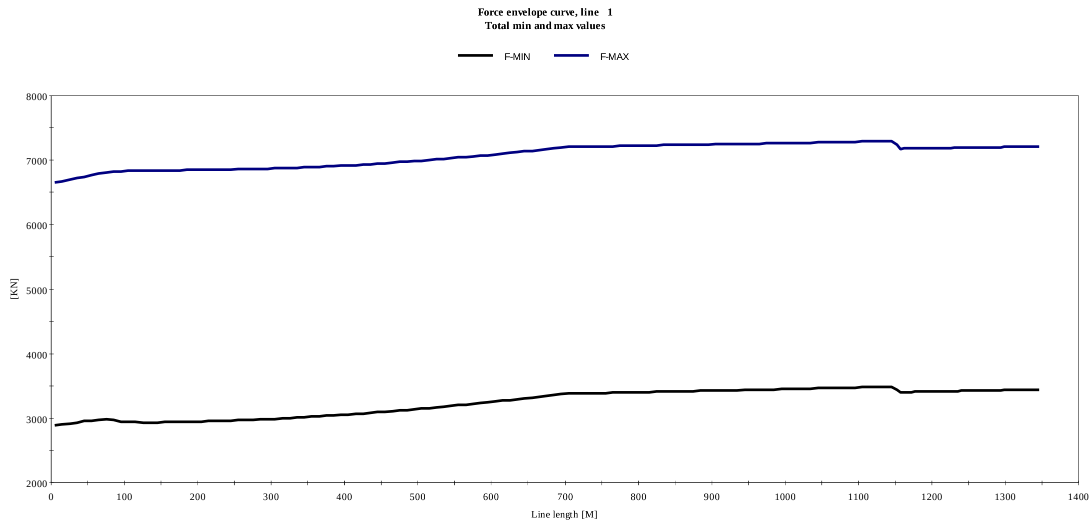

Figure 9.137 Maximum and minimum effective tension in mooring line – case2-tension 30%MBL –loaded condition - H=15m, Period 11s

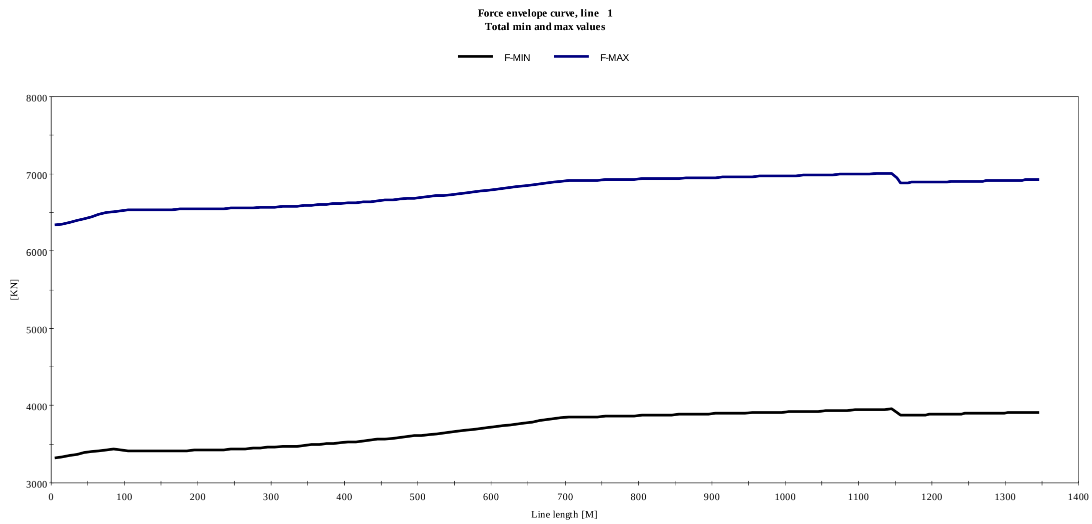

Figure 9.138 Maximum and minimum effective tension in mooring line – case2-tension 30%MBL –loaded condition - H=15m, Period 12s

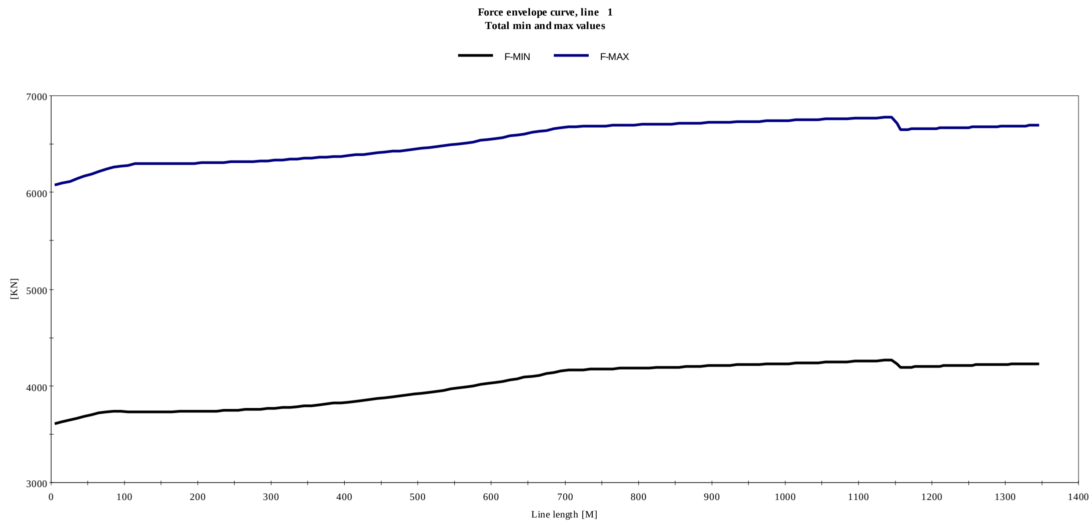

Figure 9.139 Maximum and minimum effective tension in mooring line – case2-tension 30%MBL –loaded condition - H=15m, Period 13s

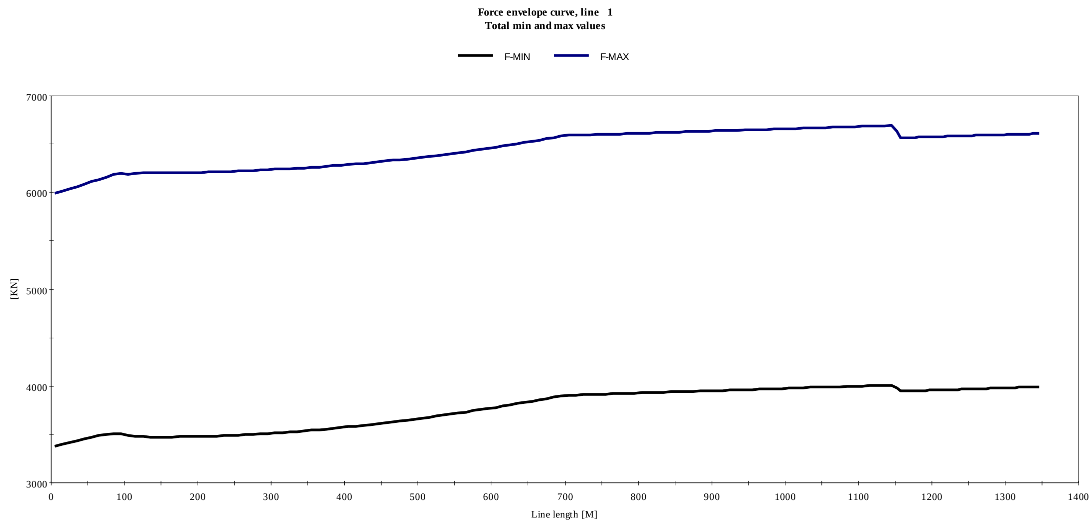

Figure 9.140 Maximum and minimum effective tension in mooring line – case2-tension 30%MBL –loaded condition - H=15m, Period 14s

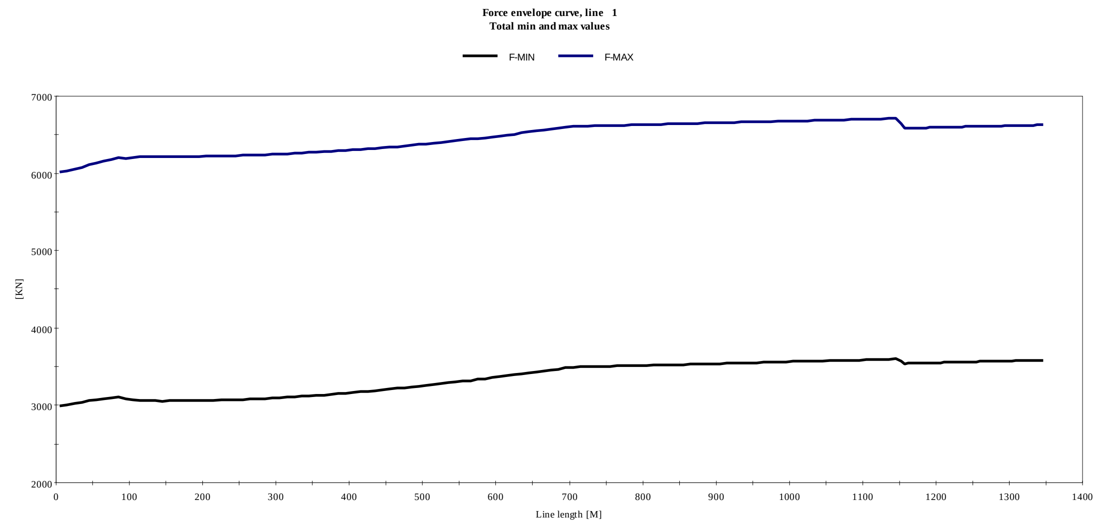

Figure 9.141 Maximum and minimum effective tension in mooring line – case2-tension 30%MBL –loaded condition - H=15m, Period 15s

The maximum and minimum effective tension in mooring line and the maximum and minimum line displacement in X, Y and Z directions are summarized in tables 9.46 and 9.47.

The following results and behaviours are observed:

- The lowest value for minimum dynamic axial force is obtained in highest seastate with wave height 15m and wave period 15s.
- The highest value for maximum dynamic axial force is obtained in highest seastate with wave height 15m and wave period 15s.
- The lowest value for minimum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 15m and wave period 15s.
- The highest value for maximum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 15m and wave period 15s.

Table 9-46 Force envelope curves for case2-tension 30%MBL –loaded -seastate case 1

SEASTATE	FORCE ENVELOPE CURVES		
	AXIAL FORCE		
	MIN DYNAMIC	STATIC FORCE	MAX DYNAMIC
H=15m,T= 9s	-9.52E+02	5.33E+03	1.03E+03
H=15m,T=10s	-1.27E+03	5.33E+03	1.33E+03
H=15m,T= 11s	-1.88E+03	5.33E+03	2.16E+03
H=15m,T= 12s	-1.40E+03	5.33E+03	1.84E+03
H=15m,T= 13s	-1.08E+03	5.33E+03	1.58E+03
H=15m,T= 14s	-1.34E+03	5.33E+03	1.50E+03
H=15m,T=15s	-1.76E+03	5.33E+03	1.52E+03

Table 9-47 Displacement envelope curves for case2-tension 30%MBL –loaded -seastate case 1

SEASTATE	DISPLACEMENT ENVELOPE CURVE					
	X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC
H=15m,T= 9s	-1.36E+00	1.26E+00	-7.19E-01	7.72E-01	-2.96E+00	3.12E+00
H=15m,T=10s	-1.99E+00	1.77E+00	-3.33E-01	3.11E-01	-4.02E+00	4.14E+00
H=15m,T= 11s	-2.99E+00	2.40E+00	-5.87E-01	6.40E-01	-5.74E+00	6.13E+00
H=15m,T= 12s	-2.06E+00	1.95E+00	-1.11E+00	1.14E+00	-7.03E+00	7.09E+00
H=15m,T= 13s	-2.16E+00	2.54E+00	-1.55E+00	1.50E+00	-7.86E+00	7.95E+00
H=15m,T= 14s	-3.19E+00	3.65E+00	-1.82E+00	1.74E+00	-8.47E+00	8.59E+00
H=15m,T=15s	-4.07E+00	4.55E+00	-1.95E+00	1.85E+00	-8.73E+00	8.86E+00

9.4.4.2.4. Mooring line with tension 30%MBL- Regular wave H=30m, T=13-17s

For mooring line with tension 30%MBL, the maximum and minimum effective tension in regulare waves with wave height 30m and periods from 13s to 17s are shown in fgures 9.142 to 9.146.

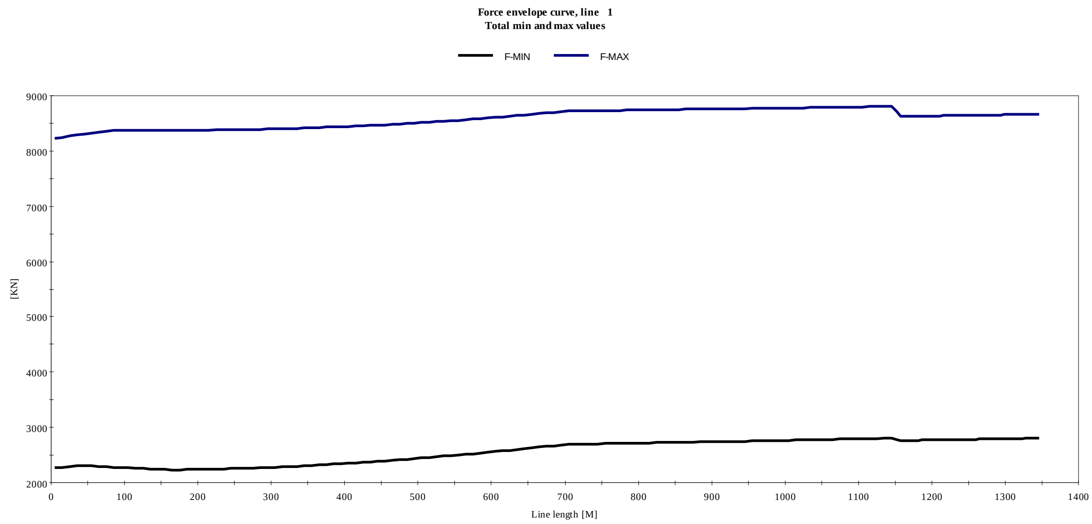

Figure 9.142 Maximum and minimum effective tension in mooring line – case2-tension 30%MBL –loaded condition - H=30m, Period 13s

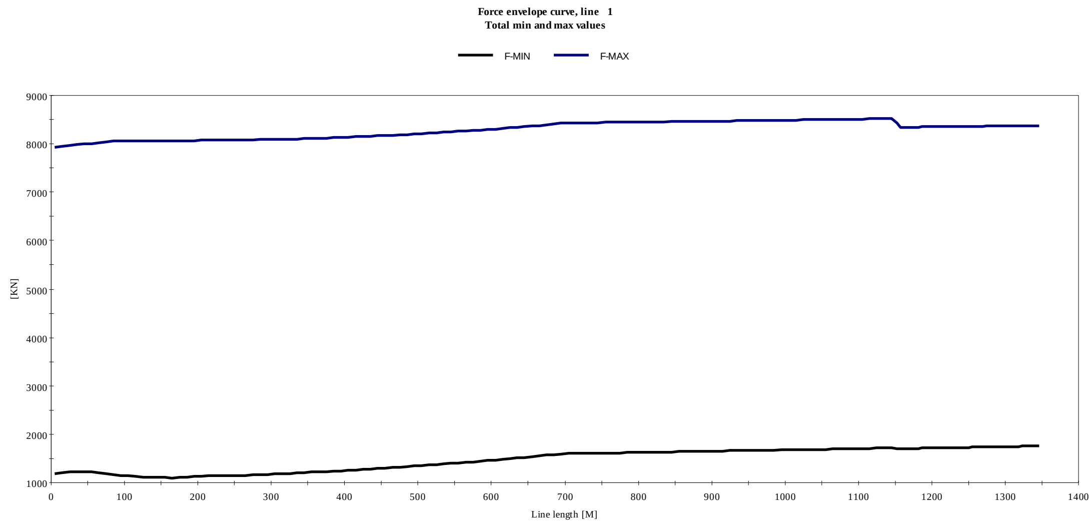

Figure 9.143 Maximum and minimum effective tension in mooring line – case2-tension 30%MBL –loaded condition - H=30m, Period 14s

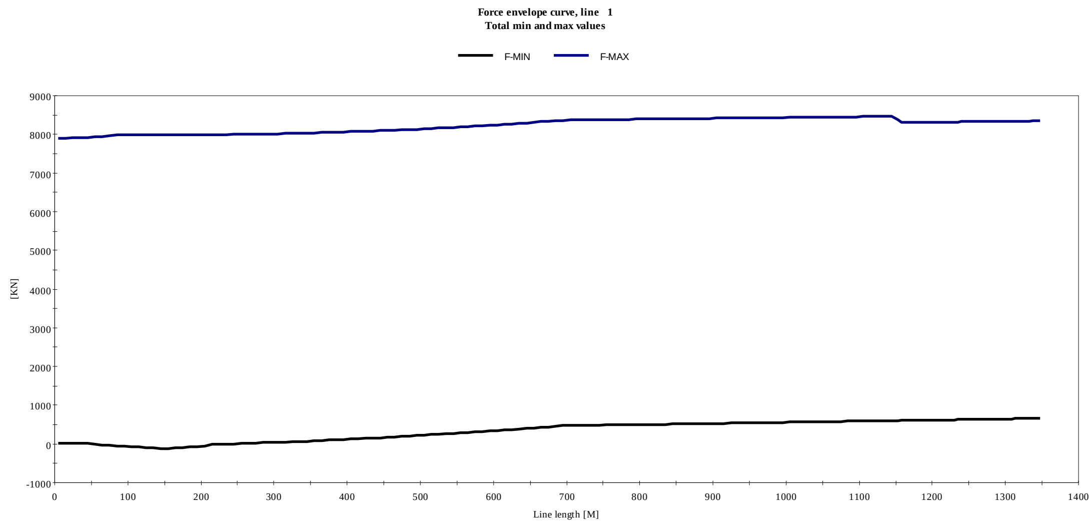

Figure 9.144 Maximum and minimum effective tension in mooring line – case2-tension 30%MBL –loaded condition - H=30m, Period 15s

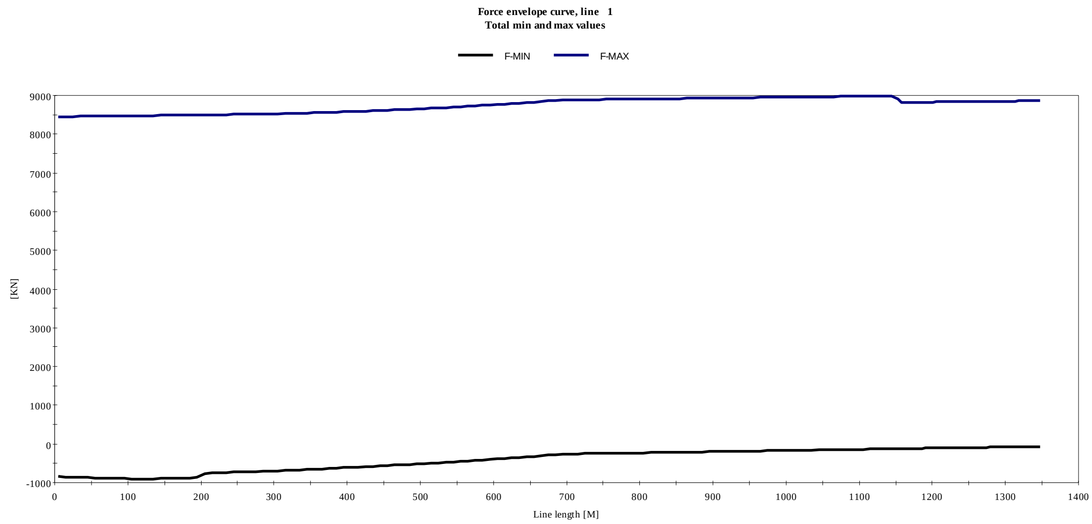

Figure 9.145 Maximum and minimum effective tension in mooring line – case2-tension 30%MBL –loaded condition - H=30m, Period 16s

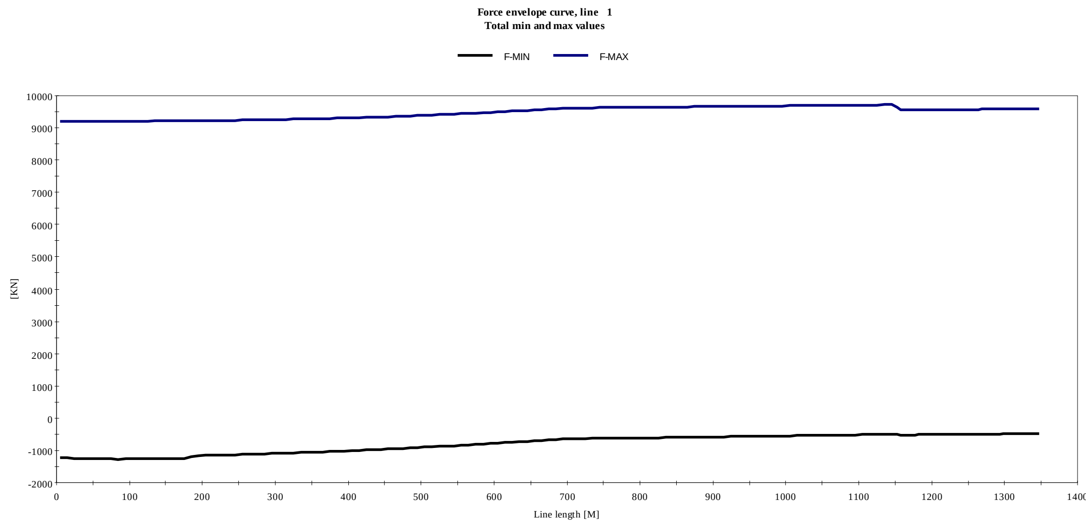

Figure 9.146 Maximum and minimum effective tension in mooring line – case2-tension 30%MBL –loaded condition - H=30m, Period 17s

The maximum and minimum effective tension in mooring line and the maximum and minimum line displacement in X, Y and Z directions are summarized in tables 9.48 and 9.49.

The following trends and behaviours are extracted:

- The lowest observed value for minimum dynamic axial force is obtained in highest seastate with wave height 30m and wave period 17s.
- The highest value for maximum dynamic axial force is obtained in highest seastate with wave height 30m and wave period 17s.
- The lowest value for minimum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 30m and wave period 17s.

The highest value for maximum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 30m and wave period 17s.

Table 9-48 Force envelope curves for case2-tension 30%MBL –loaded -seastate case 2

SEASTATE	FORCE ENVELOPE CURVES		
	AXIAL FORCE		
	MIN DYNAMIC	STATIC FORCE	MAX DYNAMIC
H=30m,T= 13s	-2.59E+03	5.33E+03	3.73E+03
H=30m,T=14s	-3.72E+03	5.33E+03	3.43E+03
H=30m,T= 15s	-4.94E+03	5.33E+03	3.38E+03
H=30m,T= 16s	-5.71E+03	5.33E+03	3.94E+03
H=30m,T= 17s	-6.06E+03	5.33E+03	4.69E+03

Table 9-49 Displacement envelope curves for case2-tension 30%MBL –loaded -seastate case2

SEASTATE	DISPLACEMENT ENVELOPE CURVE					
	X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC
H=30m,T= 13s	-4.78E+00	6.64E+00	-3.16E+00	2.64E+00	-1.62E+01	1.66E+01
H=30m,T=14s	-5.93E+00	7.76E+00	-3.74E+00	3.43E+00	-1.68E+01	1.73E+01
H=30m,T= 15s	-7.66E+00	9.57E+00	-4.03E+00	3.65E+00	-1.73E+01	1.78E+01
H=30m,T= 16s	-9.09E+00	1.09E+01	-4.23E+00	3.76E+00	-1.75E+01	1.80E+01
H=30m,T= 17s	-1.03E+01	1.18E+01	-4.36E+00	3.76E+00	-1.74E+01	1.97E+01

9.4.4.2.5. Mooring line with tension 45%MBL- Regular wave H=15m, T=9-15s

For mooring line with tension 45%MBL, the maximum and minimum effective tension in regulare waves with wave height 15m and periods from 9s to 15s are shown in fgures 9.147 to 9.153.

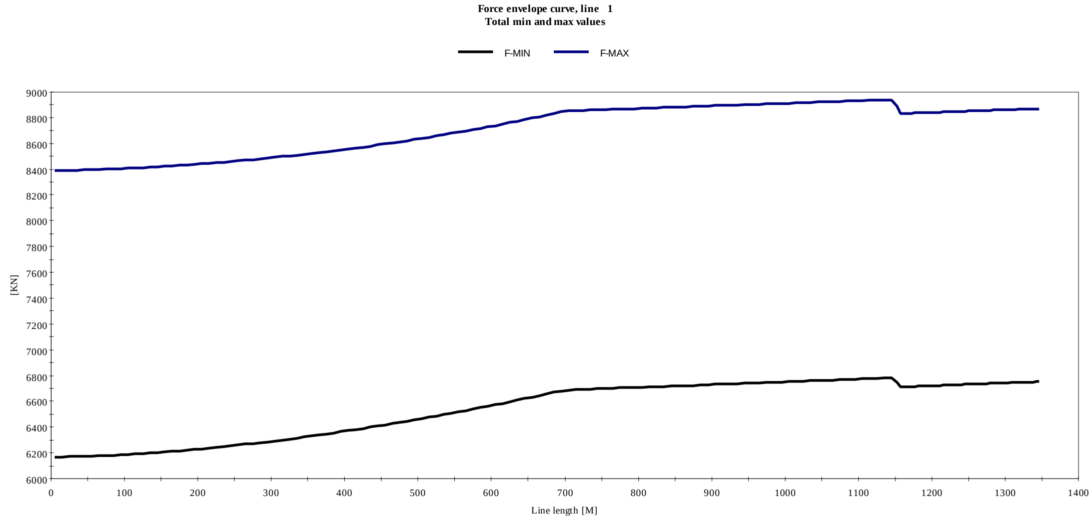

Figure 9.147 Maximum and minimum effective tension in mooring line – case2-tension 45%MBL –loaded condition - H=15m, Period 9s

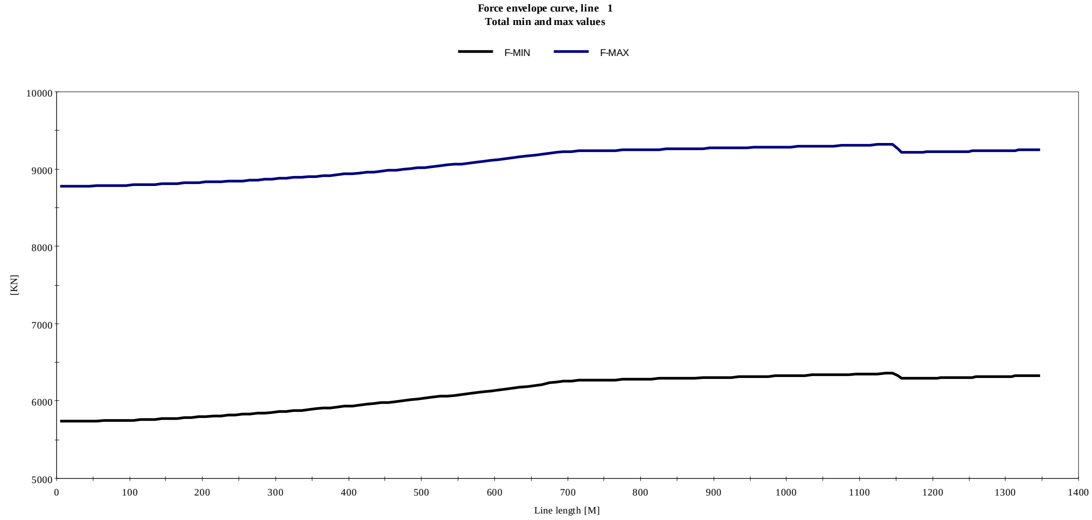

Figure 9.148 Maximum and minimum effective tension in mooring line – case2-tension 45%MBL –loaded condition - H=15m, Period 10s

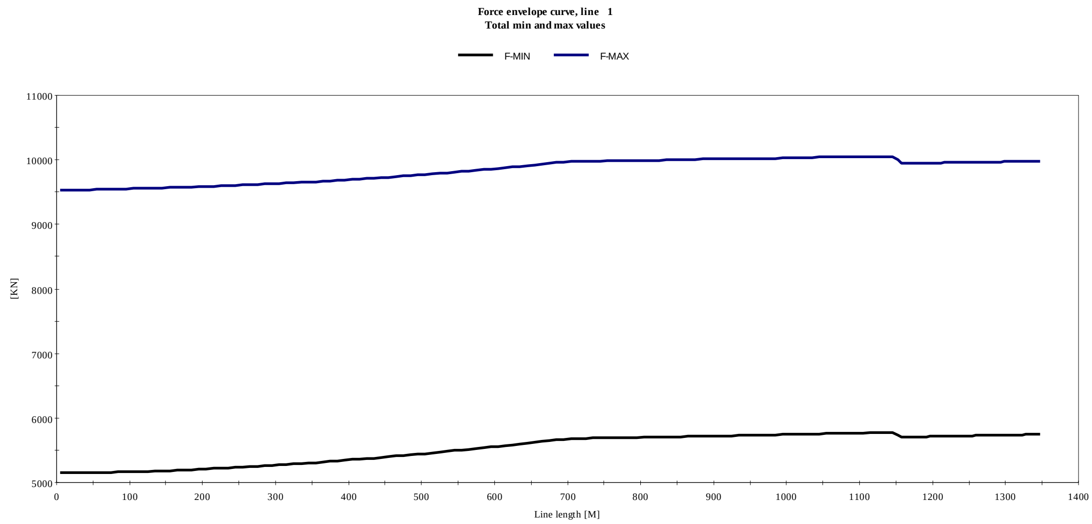

Figure 9.149 Maximum and minimum effective tension in mooring line – case2-tension 45%MBL –loaded condition - H=15m, Period 11s

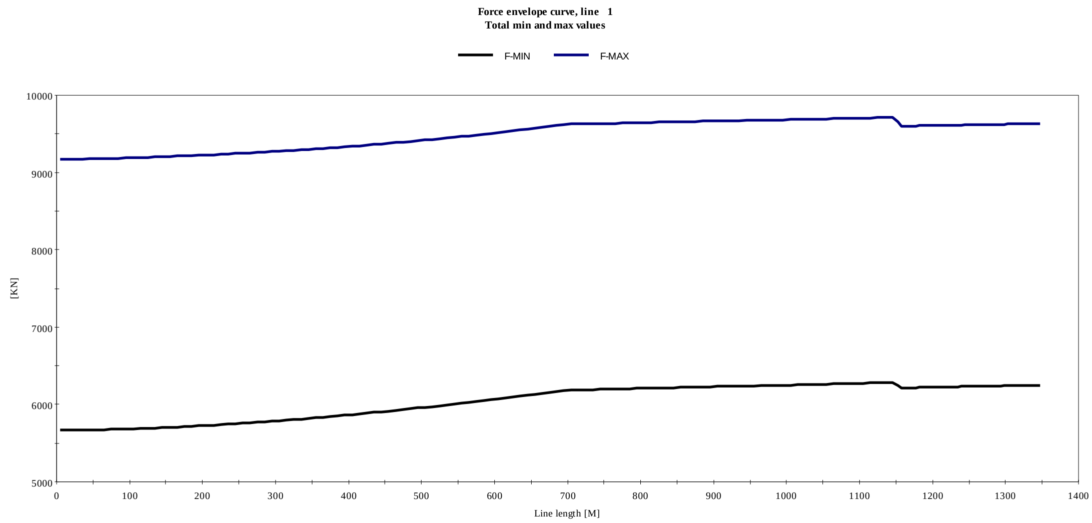

Figure 9.150 Maximum and minimum effective tension in mooring line – case2-tension 45%MBL –loaded condition - H=15m, Period 12s

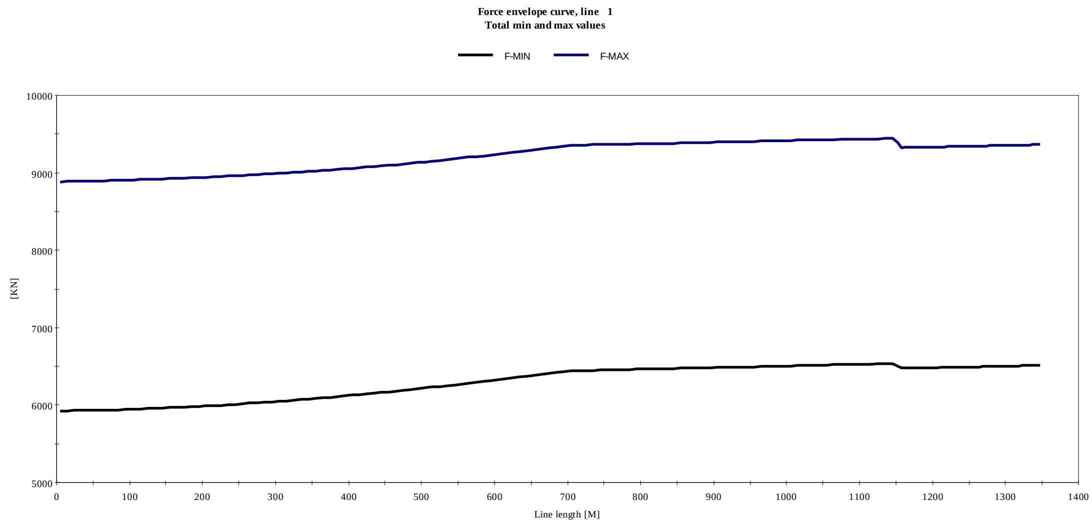

Figure 9.151 Maximum and minimum effective tension in mooring line – case2-tension 45%MBL –loaded condition - H=15m, Period 13s

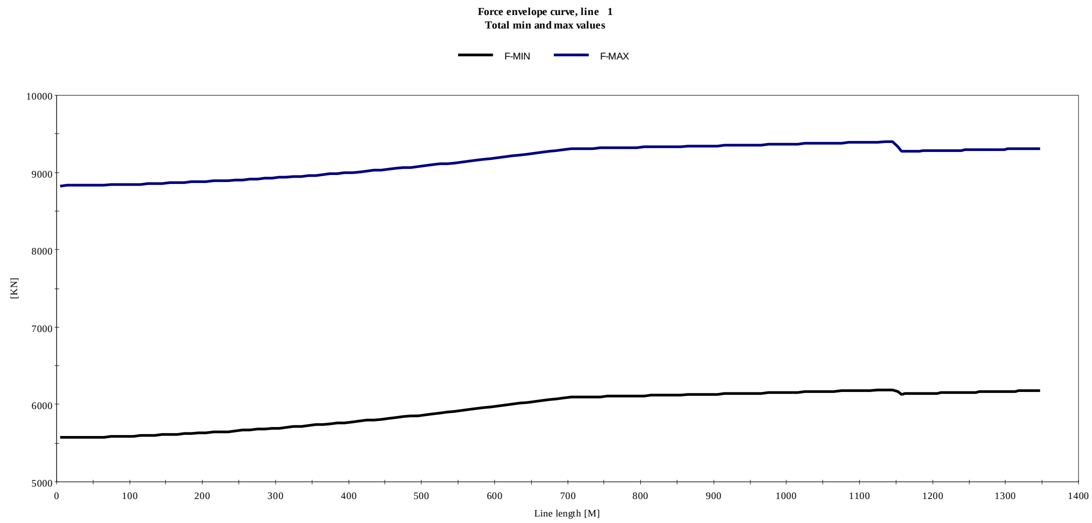

Figure 9.152 Maximum and minimum effective tension in mooring line – case2-tension 45%MBL –loaded condition - H=15m, Period 14s

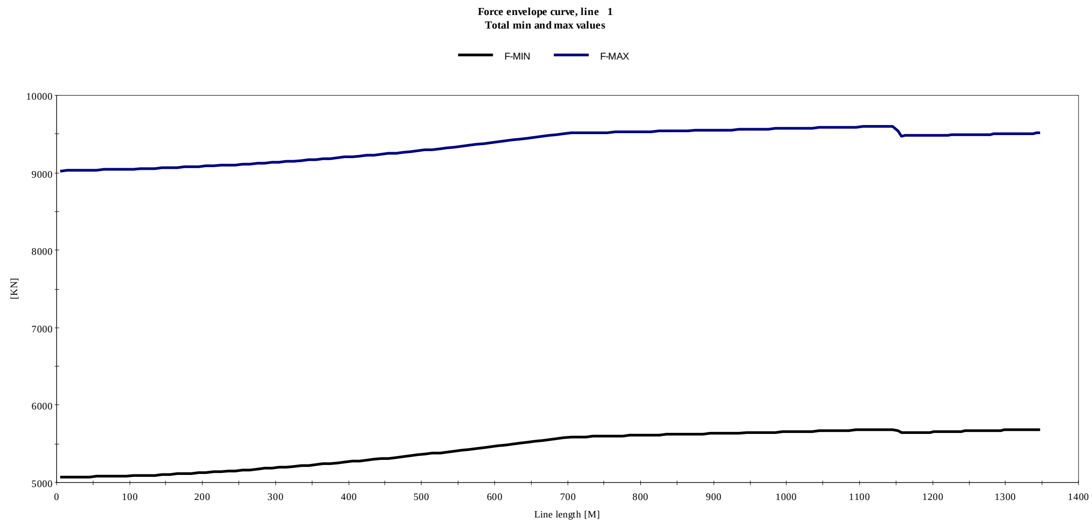

Figure 9.153 Maximum and minimum effective tension in mooring line – case2-tension 45%MBL –loaded condition - H=15m, Period 15s

The maximum and minimum effective tension in mooring line and the maximum and minimum line displacement in X, Y and Z directions are summarized in tables 9.50 and 9.51.

The following results and behaviours are observed:

- The lowest value for minimum dynamic axial force is obtained in highest seastate with wave height 15m and wave period 15s.
- The highest value for maximum dynamic axial force is obtained in highest seastate with wave height 15m and wave period 15s.
- The lowest value for minimum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 15m and wave period 15s.
- The highest value for maximum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 15m and wave period 15s.

Table 9-50 Force envelope curves for case2-tension 45%MBL –loaded -seastate case 1

SEASTATE	FORCE ENVELOPE CURVES		
	AXIAL FORCE		
	MIN DYNAMIC	STATIC FORCE	MAX DYNAMIC
H=15m,T= 9s	-1.08E+03	7.84E+03	1.14E+03
H=15m,T=10s	-1.52E+03	7.84E+03	1.52E+03
H=15m,T= 11s	-2.11E+03	7.84E+03	2.28E+03
H=15m,T= 12s	-1.59E+03	7.84E+03	1.92E+03
H=15m,T= 13s	-1.28E+03	7.79E+03	1.57E+03
H=15m,T= 14s	-1.68E+03	7.84E+03	1.58E+03
H=15m,T=15s	-2.18E+03	7.84E+03	1.78E+03

Table 9-51 Displacement envelope curves for case2-tension 45%MBL –loaded -seastate case 1

SEASTATE	DISPLACEMENT ENVELOPE CURVE					
	X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC
H=15m,T= 9s	-9.07E-01	8.81E-01	-8.31E-01	8.14E-01	-2.30E+00	2.46E+00
H=15m,T=10s	-1.28E+00	1.21E+00	-3.46E-01	3.27E-01	-3.40E+00	3.49E+00
H=15m,T= 11s	-1.93E+00	1.78E+00	-6.00E-01	6.34E-01	-5.74E+00	5.76E+00
H=15m,T= 12s	-1.55E+00	1.49E+00	-1.11E+00	1.11E+00	-7.03E+00	7.09E+00
H=15m,T= 13s	-2.16E+00	2.54E+00	-1.55E+00	1.50E+00	-7.86E+00	7.95E+00
H=15m,T= 14s	-3.19E+00	3.65E+00	-1.82E+00	1.74E+00	-8.47E+00	8.59E+00
H=15m,T=15s	-4.07E+00	4.55E+00	-1.95E+00	1.85E+00	-8.73E+00	8.86E+00

9.4.4.2.6. Mooring line with tension 45%MBL- Regular wave H=30m, T=13-17s

For mooring line with tension 45%MBL, the maximum and minimum effective tension in regulare waves with wave height 30m and periods from 13s to 17s are shown in fgures 9.154 to 9.158.

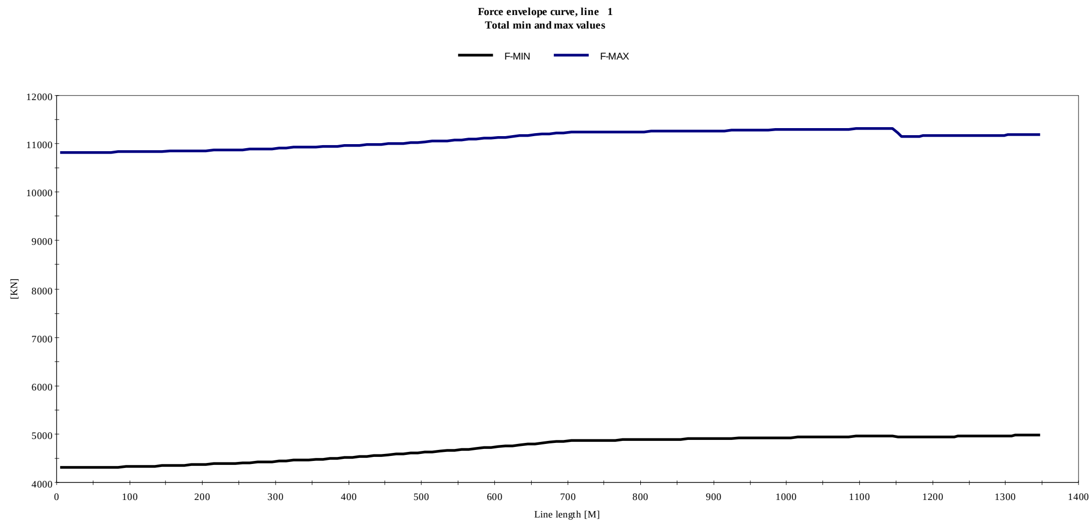

Figure 9.154 Maximum and minimum effective tension in mooring line – case2-tension 45%MBL –loaded condition - H=30m, Period 13s

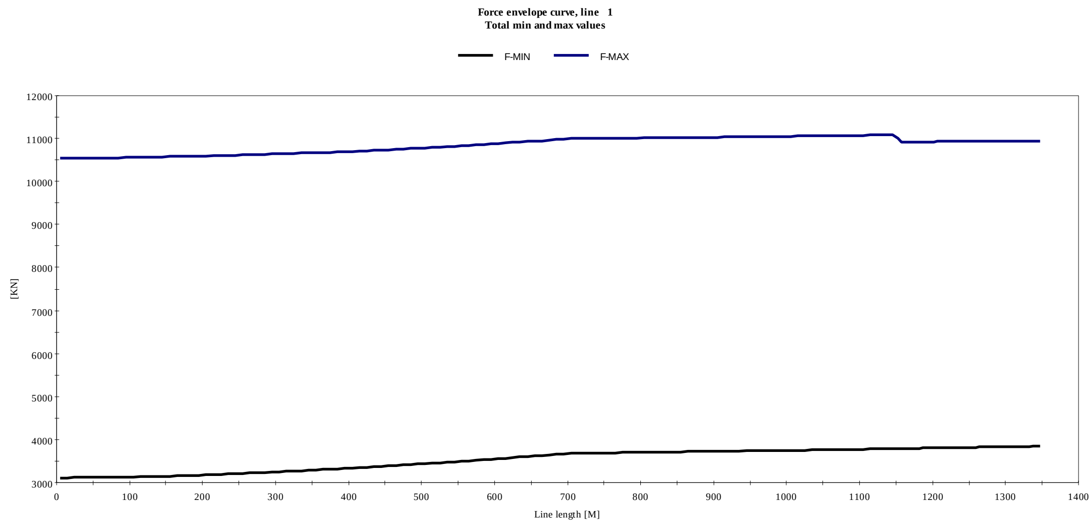

Figure 9.155 Maximum and minimum effective tension in mooring line – case2-tension 45%MBL –loaded condition - H=30m, Period 14s

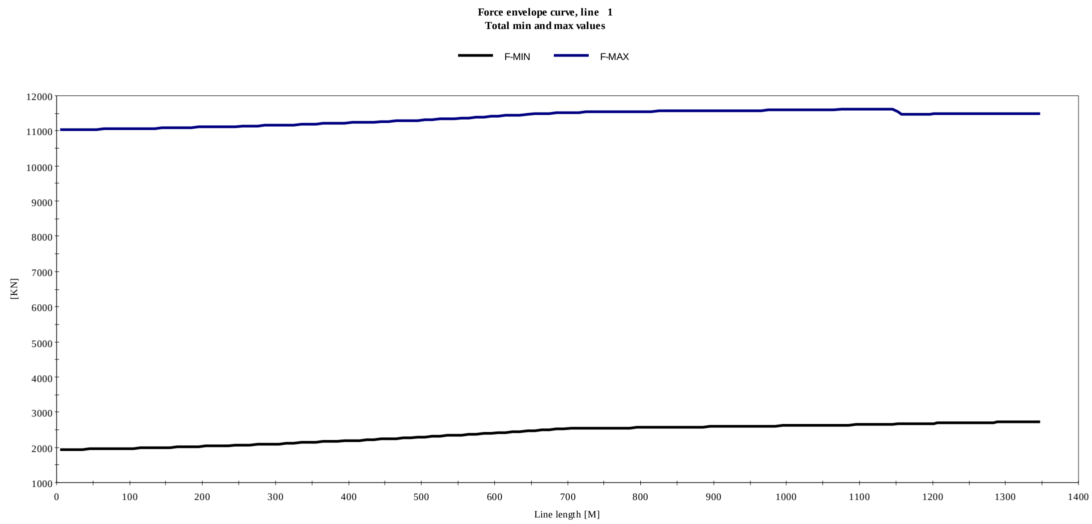

Figure 9.156 Maximum and minimum effective tension in mooring line – case2-tension 45%MBL –loaded condition - H=30m, Period 15s

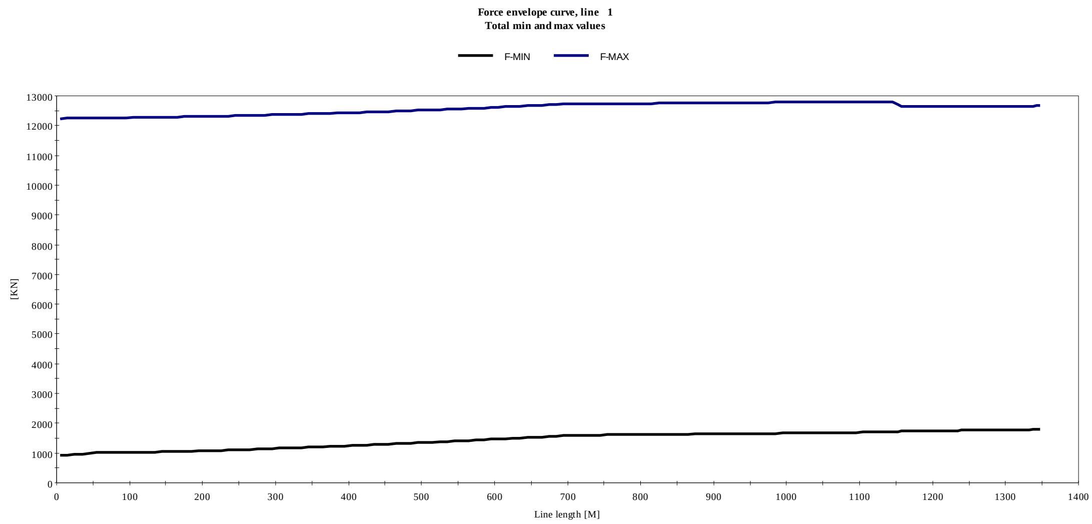

Figure 9.157 Maximum and minimum effective tension in mooring line – case2-tension 45%MBL –loaded condition - H=30m, Period 16s

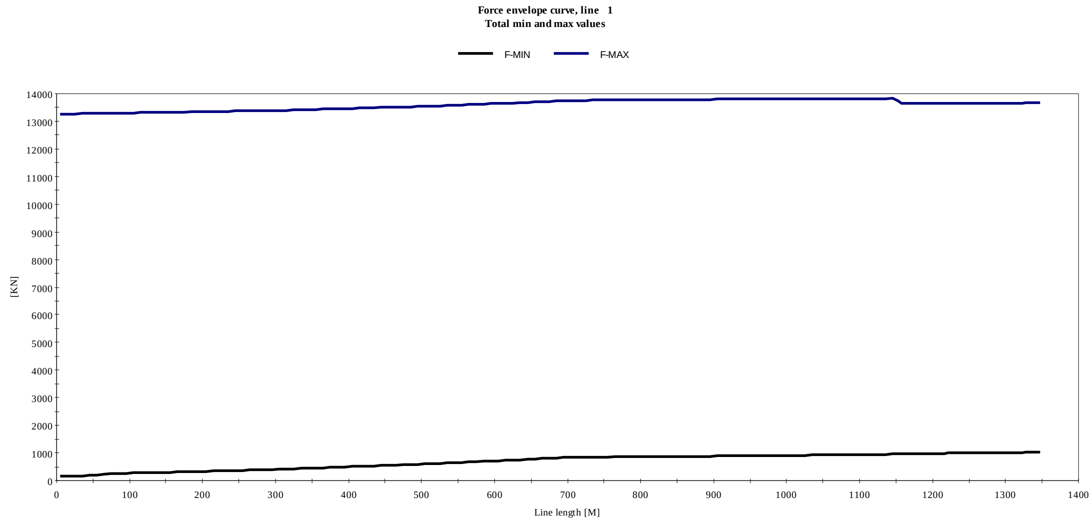

Figure 9.158 Maximum and minimum effective tension in mooring line – case2-tension 45%MBL –loaded condition - H=30m, Period 17s

The maximum and minimum effective tension in mooring line and the maximum and minimum line displacement in X, Y and Z directions are summarized in tables 9.52 and 9.53.

The following trends and behaviours are extracted:

- The lowest observed value for minimum dynamic axial force is obtained in highest seastate with wave height 30m and wave period 17s.
- The highest value for maximum dynamic axial force is obtained in highest seastate with wave height 30m and wave period 17s.
- The lowest value for minimum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 30m and wave period 17s.
- The highest value for maximum dynamic displacement in X, Y and Z directions are obtained in highest seastate with wave height 30m and wave period 17s.

Table 9-52 Force envelope curves for case2-tension 45%MBL –loaded -seastate case 2

SEASTATE	FORCE ENVELOPE CURVES		
	AXIAL FORCE		
	MIN DYNAMIC	STATIC FORCE	MAX DYNAMIC
H=30m,T= 13s	-2.94E+03	7.84E+03	3.56E+03
H=30m,T=14s	-4.15E+03	7.84E+03	3.29E+03
H=30m,T= 15s	-5.32E+03	7.84E+03	3.79E+03
H=30m,T= 16s	-6.33E+03	7.84E+03	5.00E+03
H=30m,T= 17s	-7.10E+03	7.84E+03	6.03E+03

Table 9-53 Displacement envelope curves for case2-tension 45%MBL –loaded -seastate case2

SEASTATE	DISPLACEMENT ENVELOPE CURVE					
	X-DIRECTION		Y-DIRECTION		Z-DIRECTION	
	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC	MIN DYNAMIC	MAX DYNAMIC
H=30m,T= 13s	-4.78E+00	6.64E+00	-3.16E+00	2.64E+00	-1.62E+01	1.66E+01
H=30m,T=14s	-5.93E+00	7.76E+00	-3.74E+00	3.43E+00	-1.68E+01	1.73E+01
H=30m,T= 15s	-7.66E+00	9.57E+00	-4.03E+00	3.65E+00	-1.73E+01	1.78E+01
H=30m,T= 16s	-9.09E+00	1.09E+01	-4.23E+00	3.76E+00	-1.75E+01	1.80E+01
H=30m,T= 17s	-1.03E+01	1.18E+01	-4.36E+00	3.76E+00	-1.74E+01	1.83E+01

Conclusion

This project gives a brief description about different types of floating production platforms. Mooring systems which are used for securing these floating platforms are summarized. A variety of materials are used in mooring lines. We have described them briefly and discussed their main specifications. Additionally, we have studied environmental loads acting on mooring lines, and corresponding methods for computing the load effects on mooring lines.
Applicable standards and guidelines for mooring analysis have been reviewed. Finally, hydrodynamic coefficients are calculated using DNV-OS-301 and DNV-RP-C205.

We have chosen the RIFLEX software due to its advantages comparing to other software. Mooring lines are modeled and their analyses are done using RIFLEX modeling and analysis capabilities. We have faced several problems, including: the software is not well documented, and it was not user friendly. Moreover, Multiple standards have been reviewed, comprising: ISO 19901-7, DNV-OS-E301, DNV-RP-C205, API RP 2SK, GL Noble Denton. We focused mainly on DNV-OS-E301, DNV-RP-C205 for calculation.

Two mooring line cases were introduced and studied. These cases differ in the mooring line type, static tension, water depth and seasate. 24 cases are studied for a variety of seasates. For each case, the minimum and maximum axial forces of the given line are calculated. Moreover, their corresponding displacement in the X, Y, Z directions are determined. Having these results, we can predict the line behavior under different environmental conditions. As it was expected, for a longer period we have reached the line’s axial force and displacement extremes. Although several exceptions are observed, in almost 60 percent of cases the prediction was true. Analyzing exception cases provide us with good opportunities for future academic research.

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APPENDIX A- RIFLEX INPUT FILES

INPMOD FILE (CASE1-BALLASTED-TENSION 15%MBL-H=15m , T=9s)

```
'-----------------------------------------------------------------------------
'Static and Dynamic Response Analysis of mooring system
'-----------------------------------------------------------------------------
'mooring system: catenary
'depth: 100m
'floatar: suezmax vessel
'modeling: standard AR system
'element type: beam
'created by: Leila
'-----------------------------------------------------------------------------
INPMOD IDENTIFICATION TEXT 3.4
****************************************
****************************************
****************************************
'
INPMOD PRINT SWITCH
0 0 0 0 0 0 0 0 0 0
'
  UNIT NAME SPEC
' ut   ul   um   uf   grav       gcons
  SEC  M    MG   KN  .98100E+01  .10000E+01
'-----------------------------------------------------------------------------
  NEW SING RISE
' atyps   idris
  AR      SYS
'-----------------------------------------------------------------------------
  ARBI SYST AR
' nsnod   nlin   nsnfix   nves    nricon   nspr    nakc
   2      1       2       1       0       0       0
' ibtang   zbot     ibot3d
   1     -100.0   0
' stfbot   stfaxi   stflat   friaxi   frilat
  100.     10.      100.     0.7      0.7
'
' ilinty  isnod1   isnod2
' -----------------  1 Line 4:SEGMENTS
' -----------------  SEG1: MOORING LINE1 145mm studless chain
' -----------------  SEG2: MOORING LINE2 135mm steel wire rope
' -----------------  SEG3: MOORING LINE3 145mm studless chain
' -----------------  SEG4: MOORING LINE4 135mm steel wire rope
   1      1      2
'
'----------------- Nodes with prescribed degrees of freedom
' -----------------  1: Anchor
' isnod ipos  ix   iy   iz   irx  iry  irz  chcoo   chupro
```

```
  1    0   1    1    1    0    0    0    GLOBAL         NO
'    x0       y0     z0       x1        y1       z1      rot    dir
' Ballast:
'   Static Tension =  2070 kN
'   Static Tension =  4140 kN
'   Static Tension =  6210 kN
  -1277.097    0.0    -100.0   -1268.5     0.0    -100.0     0.0    0.0
' -1277.097    0.0    -100.0   -1273.5     0.0    -100.0     0.0    0.0
' -1277.097    0.0    -100.0   -1277.0     0.0    -100.0     0.0    0.0
' Loaded:
'   Static Tension =  2070 kN
'   Static Tension =  4140 kN
'   Static Tension =  6210 kN
' -1277.539    0.0    -100.0   -1270.2     0.0    -100.0     0.0    0.0
' -1277.539    0.0    -100.0   -1274.7     0.0    -100.0     0.0    0.0
' -1277.539    0.0    -100.0   -1278.0     0.0    -100.0     0.0    0.0
'
' -----------------  2: Turret
  2    1    1    1    1    0    0    0        VESSEL      YES
'    x0       y0     z0       x1        y1       z1      rot    dir
' Ballast:
    0.0      0.0    -13.84       0.0       0.0     -13.84   0.0  0.0
' Loaded:
'   0.0      0.0    -20.67       0.0       0.0     -20.67   0.0  0.0
' -----------------
'
' ives   idwftr   xg       yg       zg      dirx
  1      VES1   86.93   -23.29     0.0     165.0
'------------------------------------------------------------------------------
  NEW LINE DATA
'------------------  MOORING LINE
' -----------------  1 Line 4:SEGMENTS
' -----------------  SEG1: MOORING LINE1 145mm studless chain
' -----------------  SEG2: MOORING LINE2 135mm steel wire rope
' -----------------  SEG3: MOORING LINE3 145mm studless chain
' -----------------  SEG4: MOORING LINE4 135mm steel wire rope
' ilinty   nseg   icnlty   ifluty
   1       4       0        0
' icmpty   icn1ty  iexwty   nelseg   slgth
   2       0       0        20      200.000
   3       0       0        50      500.000
   2       0       0        80      400.000
   3       0       0        36      180.000
'------------------------------------------------------------------------------
  NEW COMP CRS1                      ------ studless Chain:
' icmpty   temp
   2       .2000E+02
' ams      ae       ai       rgyr
  0.4205  .05357   .00000   .00000
' iea      iej      igt      ipress     imf
```

```
  1       0       0       0         0
' ea
 1639000
' cdx      cdy      amx      amy     cdlx   cdly
'                               ------ Cdn/Cdt/Cmn/Cmt = 1.5/0.20/1.0/0.20
 0.08410  0.17835  0.01098   0.05491    0.00   0.00
' tb        ycurmx
 13800.0    .3000E+00
'-----------------------------------------------------------------------------
 NEW COMP CRS1                    ------ Wire:
' icmpty   temp
  3       .2000E+02
' ams      ae       ai       rgyr
 0.07102  .01317   .00000   .00000
' iea      iej      igt      ipress     imf
  1       0       0       0         0
' ea
 1283000
' cdx     cdy     amx     amy     cdlx   cdly
'                               ------ Cdn/Cdt/Cmn/Cmt = 1.2/0.00/1.0/0.00
 0.00000 0.08303 0.00000 0.01467 0.00   0.00
' tb        ycurmx
 13800.0    .3000E+00
'----------------------------------------------------------------------------
 ENVI IDEN
 Environemntal data
' idenv
 ENV
'----------------------------------------------------------------------------
 WATE AND WAVE
' wdepth    noirw   norw   ncusta
 100.0       0      1      1
'----------------------------------------------------------------------------
 ENVI CONS
' airden     watden     wakivi
 .1300E-02  .1025E+01  .1880E-05
'----------------------------------------------------------------------------
 REGU WAVE DATA
' inrwc   amplit   period   wavdir
' Dynamic:
   1     7.50     9.0      0.00
'   1     7.50    10.0      0.00
'   1     7.50    11.0      0.00
'   1     7.50    12.0      0.00
'   1     7.50    13.0      0.00
'   1     7.50    14.0      0.00
'   1     7.50    15.0      0.00
'
'   1    15.00    13.0      0.00
'   1    15.00    14.0      0.00
```

```
'   1    15.00    15.0      0.00
'   1    15.00    16.0      0.00
'   1    15.00    17.0      0.00
'-----------------------------------------------------------------------------
  NEW CURR STAT
' icusta  nculev
    1        3
'  curlev     curdir     curvel
     0.000    0.000      0.000
   -50.000    0.000      0.000
  -100.000    0.000      0.000
'-----------------------------------------------------------------------------
'  TRAN FUNC FILE
' chftra
'=============================================================================
====
SUPPORT VESSEL IDENTIFICATION
'=============================================================================
====
' Reference data used scaling RAO in roll, pitch and yaw:
' DEPTH=  100.0     GRAV =  9.810
'txmo1, 1 line

'idhftr
 VES1
'-----------------------------------------------------------
 HFTRAN REFERENCE POSITION
'-----------------------------------------------------------
' zg
  0.
'-----------------------------------------------------------
 HFTRANSFER CONTROL DATA
'-----------------------------------------------------------
'ndhftr  nwhftr  isymhf  itypin
      9      31       1       2
'-----------------------------------------------------------
 WAVE DIRECTIONS
'-----------------------------------------------------------
'ihead  head
      1        0.00000
      2        30.0000
      3        60.0000
      4        90.0000
      5        120.000
      6        135.000
      7        150.000
      8        165.000
      9        180.000
'-----------------------------------------------------------
 WAVE FREQUENCIES
```

'---

'ifreq	whftr
1	0.157080
2	0.179520
3	0.209440
4	0.251327
5	0.273182
6	0.285599
7	0.314159
8	0.330694
9	0.349066
10	0.369599
11	0.392699
12	0.418879
13	0.448799
14	0.465421
15	0.483322
16	0.502655
17	0.523599
18	0.546364
19	0.571199
20	0.598399
21	0.628319
22	0.661388
23	0.698132
24	0.739198
25	0.785398
26	0.837758
27	0.897598
28	0.966644
29	1.04720
30	1.25664
31	1.57080

'---

HFTRANSFER FUNCTION SURGE

'---

'idir	ifreq	ampl	phase
1	1	1.943	-92.00
1	2	1.688	-93.00
1	3	1.428	-93.00
1	4	1.158	-95.00
1	5	1.045	-95.00
1	6	0.9859	-95.00
1	7	0.8620	-96.00
1	8	0.7956	-97.00
1	9	0.7250	-97.00
1	10	0.6485	-98.00
1	11	0.5640	-99.00
1	12	0.4687	-100.00
1	13	0.3598	-102.00

1	14	0.2998	-103.00
1	15	0.2367	-104.00
1	16	0.1721	-104.00
1	17	0.1086	-104.00
1	18	0.5021E-01	-97.00
1	19	0.1297E-01	-15.00
1	20	0.4191E-01	45.00
1	21	0.6081E-01	46.00
1	22	0.5786E-01	40.00
1	23	0.3780E-01	28.00
1	24	0.1810E-01	-2.00
1	25	0.1323E-01	-45.00
1	26	0.8653E-02	-37.00
1	27	0.6934E-02	67.00
1	28	0.7598E-02	132.00
1	29	0.5450E-02	-109.00
1	30	0.3163E-02	-114.00
1	31	0.1412E-02	-171.00
2	1	1.706	-92.00
2	2	1.488	-92.00
2	3	1.269	-93.00
2	4	1.045	-94.00
2	5	0.9518	-94.00
2	6	0.9042	-95.00
2	7	0.8052	-95.00
2	8	0.7530	-96.00
2	9	0.6980	-96.00
2	10	0.6391	-97.00
2	11	0.5746	-98.00
2	12	0.5021	-99.00
2	13	0.4185	-100.00
2	14	0.3715	-101.00
2	15	0.3209	-102.00
2	16	0.2672	-103.00
2	17	0.2113	-104.00
2	18	0.1552	-105.00
2	19	0.1006	-107.00
2	20	0.4990E-01	-111.00
2	21	0.7129E-02	-138.00
2	22	0.2295E-01	70.00
2	23	0.3184E-01	61.00
2	24	0.2495E-01	52.00
2	25	0.1399E-01	23.00
2	26	0.1350E-01	-26.00
2	27	0.1155E-01	-31.00
2	28	0.4253E-02	70.00
2	29	0.5910E-02	154.00
2	30	0.3684E-02	99.00
2	31	0.1252E-02	-47.00
3	1	1.011	-90.00

3	2	0.8906	-91.00
3	3	0.7709	-91.00
3	4	0.6529	-92.00
3	5	0.6064	-92.00
3	6	0.5833	-92.00
3	7	0.5374	-93.00
3	8	0.5146	-93.00
3	9	0.4918	-93.00
3	10	0.4690	-94.00
3	11	0.4458	-94.00
3	12	0.4217	-95.00
3	13	0.3957	-96.00
3	14	0.3813	-96.00
3	15	0.3657	-97.00
3	16	0.3485	-99.00
3	17	0.3295	-100.00
3	18	0.3083	-102.00
3	19	0.2844	-105.00
3	20	0.2554	-111.00
3	21	0.2167	-119.00
3	22	0.1641	-131.00
3	23	0.1060	-144.00
3	24	0.5992E-01	-157.00
3	25	0.3366E-01	-176.00
3	26	0.2383E-01	163.00
3	27	0.1938E-01	152.00
3	28	0.1110E-01	157.00
3	29	0.2595E-02	-98.00
3	30	0.3712E-02	85.00
3	31	0.1333E-02	64.00
4	1	0.1882E-01	2.00
4	2	0.1426E-01	2.00
4	3	0.1035E-01	3.00
4	4	0.7104E-02	4.00
4	5	0.6008E-02	4.00
4	6	0.5505E-02	4.00
4	7	0.4607E-02	3.00
4	8	0.4218E-02	2.00
4	9	0.3880E-02	-1.00
4	10	0.3606E-02	-5.00
4	11	0.3432E-02	-12.00
4	12	0.3434E-02	-23.00
4	13	0.3796E-02	-40.00
4	14	0.4223E-02	-51.00
4	15	0.4914E-02	-62.00
4	16	0.5985E-02	-73.00
4	17	0.7623E-02	-84.00
4	18	0.1014E-01	-95.00
4	19	0.1409E-01	-109.00
4	20	0.2016E-01	-125.00

4	21	0.2852E-01	-148.00
4	22	0.3663E-01	-178.00
4	23	0.3923E-01	149.00
4	24	0.3487E-01	119.00
4	25	0.2750E-01	97.00
4	26	0.2052E-01	81.00
4	27	0.1503E-01	71.00
4	28	0.1071E-01	66.00
4	29	0.7442E-02	65.00
4	30	0.3008E-02	78.00
4	31	0.5582E-03	99.00
5	1	1.013	90.00
5	2	0.8918	91.00
5	3	0.7720	91.00
5	4	0.6538	92.00
5	5	0.6070	92.00
5	6	0.5837	92.00
5	7	0.5372	93.00
5	8	0.5138	93.00
5	9	0.4902	93.00
5	10	0.4660	93.00
5	11	0.4405	93.00
5	12	0.4126	93.00
5	13	0.3805	93.00
5	14	0.3619	93.00
5	15	0.3412	93.00
5	16	0.3181	93.00
5	17	0.2922	92.00
5	18	0.2635	92.00
5	19	0.2312	90.00
5	20	0.1937	87.00
5	21	0.1485	81.00
5	22	0.9530E-01	71.00
5	23	0.4361E-01	48.00
5	24	0.2126E-01	-24.00
5	25	0.3135E-01	-61.00
5	26	0.3448E-01	-53.00
5	27	0.3137E-01	-27.00
5	28	0.2410E-01	14.00
5	29	0.1746E-01	81.00
5	30	0.9578E-02	-96.00
5	31	0.4900E-02	-100.00
6	1	1.413	91.00
6	2	1.238	92.00
6	3	1.064	92.00
6	4	0.8885	93.00
6	5	0.8172	93.00
6	6	0.7810	94.00
6	7	0.7068	94.00
6	8	0.6682	94.00

6	9	0.6278	95.00
6	10	0.5848	95.00
6	11	0.5377	95.00
6	12	0.4841	95.00
6	13	0.4206	96.00
6	14	0.3842	96.00
6	15	0.3441	96.00
6	16	0.3006	96.00
6	17	0.2542	97.00
6	18	0.2056	97.00
6	19	0.1556	97.00
6	20	0.1047	93.00
6	21	0.5507E-01	76.00
6	22	0.2954E-01	7.00
6	23	0.4858E-01	-41.00
6	24	0.5444E-01	-46.00
6	25	0.4310E-01	-28.00
6	26	0.3139E-01	16.00
6	27	0.2799E-01	78.00
6	28	0.2632E-01	140.00
6	29	0.1788E-01	-141.00
6	30	0.9706E-02	119.00
6	31	0.4388E-02	-128.00
7	1	1.707	92.00
7	2	1.490	92.00
7	3	1.270	93.00
7	4	1.045	94.00
7	5	0.9520	94.00
7	6	0.9040	95.00
7	7	0.8039	95.00
7	8	0.7505	95.00
7	9	0.6938	96.00
7	10	0.6322	96.00
7	11	0.5635	97.00
7	12	0.4846	97.00
7	13	0.3919	98.00
7	14	0.3397	99.00
7	15	0.2840	99.00
7	16	0.2257	101.00
7	17	0.1668	103.00
7	18	0.1097	107.00
7	19	0.5689E-01	113.00
7	20	0.1061E-01	130.00
7	21	0.2790E-01	-64.00
7	22	0.5201E-01	-55.00
7	23	0.5491E-01	-43.00
7	24	0.4132E-01	-15.00
7	25	0.3324E-01	40.00
7	26	0.3489E-01	96.00
7	27	0.3115E-01	150.00

7	28	0.2101E-01	-127.00
7	29	0.1959E-01	-27.00
7	30	0.8578E-02	-77.00
7	31	0.3324E-02	143.00
8	1	1.885	92.00
8	2	1.639	93.00
8	3	1.390	93.00
8	4	1.132	94.00
8	5	1.023	95.00
8	6	0.9668	95.00
8	7	0.8481	96.00
8	8	0.7843	96.00
8	9	0.7158	97.00
8	10	0.6409	97.00
8	11	0.5570	98.00
8	12	0.4609	99.00
8	13	0.3495	100.00
8	14	0.2882	101.00
8	15	0.2242	103.00
8	16	0.1598	106.00
8	17	0.9820E-01	113.00
8	18	0.4502E-01	132.00
8	19	0.2267E-01	-144.00
8	20	0.4513E-01	-93.00
8	21	0.6004E-01	-75.00
8	22	0.5768E-01	-58.00
8	23	0.4207E-01	-27.00
8	24	0.3494E-01	30.00
8	25	0.3903E-01	83.00
8	26	0.3563E-01	133.00
8	27	0.2664E-01	-157.00
8	28	0.2309E-01	-66.00
8	29	0.1534E-01	44.00
8	30	0.7579E-02	30.00
8	31	0.2862E-02	-48.00
9	1	1.945	92.00
9	2	1.689	93.00
9	3	1.429	94.00
9	4	1.159	95.00
9	5	1.045	95.00
9	6	0.9854	95.00
9	7	0.8601	96.00
9	8	0.7924	97.00
9	9	0.7197	97.00
9	10	0.6401	98.00
9	11	0.5509	98.00
9	12	0.4488	99.00
9	13	0.3313	100.00
9	14	0.2672	102.00
9	15	0.2010	104.00

9	16	0.1354	109.00
9	17	0.7468E-01	120.00
9	18	0.2990E-01	162.00
9	19	0.3752E-01	-115.00
9	20	0.5990E-01	-90.00
9	21	0.6707E-01	-75.00
9	22	0.5588E-01	-56.00
9	23	0.3697E-01	-16.00
9	24	0.3659E-01	47.00
9	25	0.4080E-01	94.00
9	26	0.3396E-01	146.00
9	27	0.2657E-01	-136.00
9	28	0.2262E-01	-50.00
9	29	0.1517E-01	72.00
9	30	0.7402E-02	69.00
9	31	0.2617E-02	10.00

'---

HFTRANSFER FUNCTION SWAY

'---

'idir	ifreq	ampl	phase
1	1	0.000	0.00
1	2	0.000	0.00
1	3	0.000	0.00
1	4	0.000	0.00
1	5	0.000	0.00
1	6	0.000	0.00
1	7	0.000	0.00
1	8	0.000	0.00
1	9	0.000	0.00
1	10	0.000	0.00
1	11	0.000	0.00
1	12	0.000	0.00
1	13	0.000	0.00
1	14	0.000	0.00
1	15	0.000	0.00
1	16	0.000	0.00
1	17	0.000	0.00
1	18	0.000	0.00
1	19	0.000	0.00
1	20	0.000	0.00
1	21	0.000	0.00
1	22	0.000	0.00
1	23	0.000	0.00
1	24	0.000	0.00
1	25	0.000	0.00
1	26	0.000	0.00
1	27	0.000	0.00
1	28	0.000	0.00
1	29	0.000	0.00
1	30	0.000	0.00

1	31	0.000	0.00
2	1	0.9852	-90.00
2	2	0.8581	-90.00
2	3	0.7300	-90.00
2	4	0.5999	-90.00
2	5	0.5473	-90.00
2	6	0.5210	-91.00
2	7	0.4696	-91.00
2	8	0.4463	-92.00
2	9	0.4283	-94.00
2	10	0.4187	-101.00
2	11	0.2689	-121.00
2	12	0.1866	-99.00
2	13	0.1631	-94.00
2	14	0.1444	-94.00
2	15	0.1221	-95.00
2	16	0.9696E-01	-98.00
2	17	0.7008E-01	-104.00
2	18	0.4382E-01	-118.00
2	19	0.2640E-01	-159.00
2	20	0.3204E-01	148.00
2	21	0.4486E-01	128.00
2	22	0.4870E-01	120.00
2	23	0.3814E-01	120.00
2	24	0.1544E-01	138.00
2	25	0.1556E-01	-101.00
2	26	0.2698E-01	-73.00
2	27	0.2085E-01	-30.00
2	28	0.1738E-01	36.00
2	29	0.9127E-02	149.00
2	30	0.4993E-02	69.00
2	31	0.1631E-02	-84.00
3	1	1.753	-90.00
3	2	1.542	-90.00
3	3	1.332	-90.00
3	4	1.127	-90.00
3	5	1.048	-90.00
3	6	1.010	-91.00
3	7	0.9424	-91.00
3	8	0.9169	-92.00
3	9	0.9062	-94.00
3	10	0.9185	-101.00
3	11	0.6176	-120.00
3	12	0.4748	-97.00
3	13	0.4712	-91.00
3	14	0.4556	-90.00
3	15	0.4327	-89.00
3	16	0.4035	-89.00
3	17	0.3681	-89.00
3	18	0.3263	-88.00

3	19	0.2778	-88.00
3	20	0.2232	-88.00
3	21	0.1639	-88.00
3	22	0.1032	-89.00
3	23	0.4530E-01	-91.00
3	24	0.8072E-02	150.00
3	25	0.4042E-01	114.00
3	26	0.5469E-01	120.00
3	27	0.4685E-01	139.00
3	28	0.3148E-01	-177.00
3	29	0.2503E-01	-111.00
3	30	0.1838E-01	69.00
3	31	0.5490E-02	50.00
4	1	2.052	-90.00
4	2	1.813	-90.00
4	3	1.578	-90.00
4	4	1.354	-90.00
4	5	1.271	-90.00
4	6	1.233	-90.00
4	7	1.168	-91.00
4	8	1.149	-92.00
4	9	1.151	-93.00
4	10	1.185	-101.00
4	11	0.8143	-119.00
4	12	0.6545	-96.00
4	13	0.6821	-90.00
4	14	0.6814	-88.00
4	15	0.6743	-87.00
4	16	0.6623	-87.00
4	17	0.6467	-86.00
4	18	0.6277	-84.00
4	19	0.6055	-83.00
4	20	0.5797	-82.00
4	21	0.5503	-80.00
4	22	0.5172	-77.00
4	23	0.4809	-74.00
4	24	0.4416	-70.00
4	25	0.3984	-65.00
4	26	0.3522	-58.00
4	27	0.3035	-49.00
4	28	0.2525	-37.00
4	29	0.2024	-21.00
4	30	0.1100	33.00
4	31	0.4548E-01	142.00
5	1	1.753	-90.00
5	2	1.542	-90.00
5	3	1.332	-90.00
5	4	1.127	-90.00
5	5	1.048	-90.00
5	6	1.011	-90.00

5	7	0.9425	-91.00
5	8	0.9169	-91.00
5	9	0.9060	-93.00
5	10	0.9168	-101.00
5	11	0.6085	-119.00
5	12	0.4704	-96.00
5	13	0.4690	-89.00
5	14	0.4539	-88.00
5	15	0.4314	-87.00
5	16	0.4026	-87.00
5	17	0.3675	-86.00
5	18	0.3262	-85.00
5	19	0.2784	-85.00
5	20	0.2247	-84.00
5	21	0.1670	-82.00
5	22	0.1087	-79.00
5	23	0.5343E-01	-74.00
5	24	0.6248E-02	-38.00
5	25	0.2945E-01	105.00
5	26	0.4291E-01	120.00
5	27	0.3677E-01	145.00
5	28	0.2543E-01	-156.00
5	29	0.3182E-01	-90.00
5	30	0.1494E-01	118.00
5	31	0.5588E-02	80.00
6	1	1.412	-90.00
6	2	1.236	-90.00
6	3	1.060	-90.00
6	4	0.8839	-90.00
6	5	0.8144	-90.00
6	6	0.7802	-90.00
6	7	0.7156	-91.00
6	8	0.6883	-91.00
6	9	0.6702	-93.00
6	10	0.6649	-101.00
6	11	0.4249	-120.00
6	12	0.3154	-95.00
6	13	0.2988	-89.00
6	14	0.2786	-88.00
6	15	0.2521	-88.00
6	16	0.2204	-87.00
6	17	0.1839	-87.00
6	18	0.1430	-88.00
6	19	0.9899E-01	-90.00
6	20	0.5447E-01	-95.00
6	21	0.1574E-01	-123.00
6	22	0.2247E-01	124.00
6	23	0.3957E-01	116.00
6	24	0.4064E-01	123.00
6	25	0.2795E-01	148.00

6	26	0.2232E-01	-146.00
6	27	0.2931E-01	-100.00
6	28	0.1626E-01	-67.00
6	29	0.1636E-01	90.00
6	30	0.1205E-01	-48.00
6	31	0.2955E-02	44.00
7	1	0.9852	-90.00
7	2	0.8582	-90.00
7	3	0.7300	-90.00
7	4	0.6000	-90.00
7	5	0.5474	-90.00
7	6	0.5210	-90.00
7	7	0.4696	-91.00
7	8	0.4462	-91.00
7	9	0.4276	-94.00
7	10	0.4150	-101.00
7	11	0.2537	-121.00
7	12	0.1805	-95.00
7	13	0.1612	-89.00
7	14	0.1434	-88.00
7	15	0.1218	-88.00
7	16	0.9731E-01	-88.00
7	17	0.7062E-01	-90.00
7	18	0.4302E-01	-95.00
7	19	0.1765E-01	-118.00
7	20	0.1418E-01	145.00
7	21	0.2788E-01	120.00
7	22	0.3232E-01	117.00
7	23	0.2490E-01	126.00
7	24	0.1355E-01	176.00
7	25	0.2102E-01	-121.00
7	26	0.2133E-01	-107.00
7	27	0.2417E-03	-150.00
7	28	0.1994E-01	92.00
7	29	0.7172E-02	126.00
7	30	0.6214E-02	114.00
7	31	0.2474E-02	-39.00
8	1	0.5049	-90.00
8	2	0.4383	-90.00
8	3	0.3707	-90.00
8	4	0.3013	-90.00
8	5	0.2728	-90.00
8	6	0.2585	-90.00
8	7	0.2298	-91.00
8	8	0.2163	-91.00
8	9	0.2047	-94.00
8	10	0.1951	-102.00
8	11	0.1149	-121.00
8	12	0.7916E-01	-94.00
8	13	0.6714E-01	-88.00

8	14	0.5726E-01	-88.00
8	15	0.4573E-01	-88.00
8	16	0.3314E-01	-89.00
8	17	0.2015E-01	-94.00
8	18	0.8233E-02	-117.00
8	19	0.7085E-02	146.00
8	20	0.1415E-01	121.00
8	21	0.1698E-01	117.00
8	22	0.1375E-01	123.00
8	23	0.6909E-02	159.00
8	24	0.9788E-02	-122.00
8	25	0.1351E-01	-109.00
8	26	0.5506E-02	-131.00
8	27	0.1125E-01	102.00
8	28	0.1030E-01	92.00
8	29	0.6577E-02	-72.00
8	30	0.1870E-02	-119.00
8	31	0.9955E-03	125.00
9	1	0.1699E-06	90.00
9	2	0.1473E-06	90.00
9	3	0.1243E-06	90.00
9	4	0.1006E-06	90.00
9	5	0.9088E-07	90.00
9	6	0.8593E-07	90.00
9	7	0.7603E-07	89.00
9	8	0.7129E-07	88.00
9	9	0.6715E-07	86.00
9	10	0.6356E-07	78.00
9	11	0.3687E-07	59.00
9	12	0.2509E-07	86.00
9	13	0.2084E-07	92.00
9	14	0.1746E-07	93.00
9	15	0.1356E-07	92.00
9	16	0.9372E-08	90.00
9	17	0.5155E-08	83.00
9	18	0.1767E-08	37.00
9	19	0.3162E-08	-48.00
9	20	0.5233E-08	-61.00
9	21	0.5601E-08	-62.00
9	22	0.3994E-08	-53.00
9	23	0.2025E-08	6.00
9	24	0.3901E-08	66.00
9	25	0.4409E-08	71.00
9	26	0.1436E-08	11.00
9	27	0.4707E-08	-78.00
9	28	0.2713E-08	-93.00
9	29	0.2866E-08	112.00
9	30	0.1009E-08	88.00
9	31	0.1610E-09	-4.00

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HFTRANSFER FUNCTION HEAVE

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'idir	ifreq	ampl	phase
1	1	0.9448	0.00
1	2	0.9260	0.00
1	3	0.8951	0.00
1	4	0.8381	0.00
1	5	0.8006	0.00
1	6	0.7765	0.00
1	7	0.7126	0.00
1	8	0.6696	0.00
1	9	0.6165	0.00
1	10	0.5504	1.00
1	11	0.4683	2.00
1	12	0.3681	5.00
1	13	0.2514	13.00
1	14	0.1909	22.00
1	15	0.1368	40.00
1	16	0.1082	73.00
1	17	0.1264	109.00
1	18	0.1735	129.00
1	19	0.2200	138.00
1	20	0.2414	141.00
1	21	0.2126	143.00
1	22	0.1394	156.00
1	23	0.1046	-163.00
1	24	0.1045	-133.00
1	25	0.7390E-01	-109.00
1	26	0.3404E-01	-61.00
1	27	0.1984E-01	29.00
1	28	0.1105E-01	129.00
1	29	0.9181E-02	-96.00
1	30	0.4922E-02	-89.00
1	31	0.2680E-02	-159.00
2	1	0.9590	0.00
2	2	0.9450	0.00
2	3	0.9218	0.00
2	4	0.8789	0.00
2	5	0.8505	0.00
2	6	0.8321	0.00
2	7	0.7830	0.00
2	8	0.7497	0.00
2	9	0.7081	0.00
2	10	0.6557	0.00
2	11	0.5894	1.00
2	12	0.5058	2.00
2	13	0.4023	5.00
2	14	0.3426	8.00
2	15	0.2781	12.00
2	16	0.2099	20.00

2	17	0.1427	35.00
2	18	0.9860E-01	72.00
2	19	0.1253	119.00
2	20	0.1954	136.00
2	21	0.2490	139.00
2	22	0.2393	137.00
2	23	0.1692	144.00
2	24	0.1066	174.00
2	25	0.8718E-01	-144.00
2	26	0.6881E-01	-109.00
2	27	0.3576E-01	-65.00
2	28	0.1768E-01	29.00
2	29	0.9928E-02	132.00
2	30	0.4841E-02	109.00
2	31	0.2259E-02	-33.00
3	1	0.9878	0.00
3	2	0.9836	0.00
3	3	0.9767	0.00
3	4	0.9640	0.00
3	5	0.9555	0.00
3	6	0.9500	0.00
3	7	0.9352	0.00
3	8	0.9250	0.00
3	9	0.9122	0.00
3	10	0.8959	0.00
3	11	0.8747	0.00
3	12	0.8472	-1.00
3	13	0.8110	-1.00
3	14	0.7886	-1.00
3	15	0.7621	-2.00
3	16	0.7299	-3.00
3	17	0.6887	-4.00
3	18	0.6325	-7.00
3	19	0.5496	-12.00
3	20	0.4223	-19.00
3	21	0.2386	-25.00
3	22	0.6658E-01	21.00
3	23	0.1563	84.00
3	24	0.2011	85.00
3	25	0.1795	91.00
3	26	0.1357	105.00
3	27	0.9026E-01	131.00
3	28	0.5620E-01	175.00
3	29	0.3896E-01	-125.00
3	30	0.1364E-01	46.00
3	31	0.3237E-02	43.00
4	1	1.002	0.00
4	2	1.003	0.00
4	3	1.005	0.00
4	4	1.008	0.00

4	5	1.011	0.00
4	6	1.012	0.00
4	7	1.017	0.00
4	8	1.021	0.00
4	9	1.026	0.00
4	10	1.033	0.00
4	11	1.042	-1.00
4	12	1.057	-1.00
4	13	1.079	-2.00
4	14	1.095	-2.00
4	15	1.115	-3.00
4	16	1.141	-4.00
4	17	1.174	-6.00
4	18	1.214	-9.00
4	19	1.256	-14.00
4	20	1.283	-21.00
4	21	1.256	-30.00
4	22	1.136	-41.00
4	23	0.9412	-51.00
4	24	0.7273	-59.00
4	25	0.5299	-63.00
4	26	0.3697	-62.00
4	27	0.2492	-58.00
4	28	0.1618	-49.00
4	29	0.1012	-34.00
4	30	0.3346E-01	17.00
4	31	0.8685E-02	123.00
5	1	0.9878	0.00
5	2	0.9836	0.00
5	3	0.9768	0.00
5	4	0.9642	0.00
5	5	0.9559	0.00
5	6	0.9505	0.00
5	7	0.9362	0.00
5	8	0.9265	0.00
5	9	0.9144	0.00
5	10	0.8992	0.00
5	11	0.8800	0.00
5	12	0.8558	1.00
5	13	0.8259	1.00
5	14	0.8087	1.00
5	15	0.7900	1.00
5	16	0.7695	1.00
5	17	0.7468	1.00
5	18	0.7203	0.00
5	19	0.6861	-3.00
5	20	0.6351	-7.00
5	21	0.5498	-15.00
5	22	0.4107	-27.00
5	23	0.2282	-42.00

5	24	0.6111E-01	-55.00
5	25	0.3963E-01	117.00
5	26	0.7048E-01	115.00
5	27	0.5708E-01	122.00
5	28	0.2946E-01	142.00
5	29	0.7059E-02	-169.00
5	30	0.7228E-02	71.00
5	31	0.1537E-02	92.00
6	1	0.9733	0.00
6	2	0.9642	0.00
6	3	0.9492	0.00
6	4	0.9213	0.00
6	5	0.9028	0.00
6	6	0.8908	0.00
6	7	0.8589	0.00
6	8	0.8371	0.00
6	9	0.8100	0.00
6	10	0.7757	1.00
6	11	0.7322	1.00
6	12	0.6770	2.00
6	13	0.6078	4.00
6	14	0.5673	5.00
6	15	0.5225	7.00
6	16	0.4731	8.00
6	17	0.4184	11.00
6	18	0.3574	14.00
6	19	0.2891	18.00
6	20	0.2140	26.00
6	21	0.1405	44.00
6	22	0.1078	85.00
6	23	0.1458	115.00
6	24	0.1629	119.00
6	25	0.1206	118.00
6	26	0.5421E-01	127.00
6	27	0.9116E-02	-168.00
6	28	0.1570E-01	-39.00
6	29	0.1495E-01	15.00
6	30	0.4203E-02	-87.00
6	31	0.6738E-03	51.00
7	1	0.9590	0.00
7	2	0.9450	0.00
7	3	0.9220	0.00
7	4	0.8795	0.00
7	5	0.8514	0.00
7	6	0.8334	0.00
7	7	0.7853	0.00
7	8	0.7528	0.00
7	9	0.7125	1.00
7	10	0.6621	1.00
7	11	0.5989	2.00

7	12	0.5203	4.00
7	13	0.4248	8.00
7	14	0.3710	11.00
7	15	0.3140	16.00
7	16	0.2555	23.00
7	17	0.1992	36.00
7	18	0.1551	57.00
7	19	0.1433	88.00
7	20	0.1721	114.00
7	21	0.2138	126.00
7	22	0.2324	131.00
7	23	0.2062	132.00
7	24	0.1352	135.00
7	25	0.5454E-01	153.00
7	26	0.2140E-01	-117.00
7	27	0.2580E-01	-44.00
7	28	0.1981E-01	5.00
7	29	0.3607E-02	122.00
7	30	0.1748E-02	73.00
7	31	0.4439E-03	-78.00
8	1	0.9486	0.00
8	2	0.9311	0.00
8	3	0.9024	0.00
8	4	0.8496	0.00
8	5	0.8149	0.00
8	6	0.7927	0.00
8	7	0.7337	0.00
8	8	0.6942	0.00
8	9	0.6454	1.00
8	10	0.5850	2.00
8	11	0.5101	3.00
8	12	0.4187	6.00
8	13	0.3116	13.00
8	14	0.2545	19.00
8	15	0.1988	30.00
8	16	0.1522	49.00
8	17	0.1307	78.00
8	18	0.1482	109.00
8	19	0.1918	128.00
8	20	0.2375	138.00
8	21	0.2607	141.00
8	22	0.2382	142.00
8	23	0.1661	145.00
8	24	0.7920E-01	164.00
8	25	0.4105E-01	-130.00
8	26	0.3912E-01	-72.00
8	27	0.2695E-01	-24.00
8	28	0.9282E-02	54.00
8	29	0.8323E-02	-173.00
8	30	0.1808E-02	156.00

8	31	0.1389E-03	88.00
9	1	0.9448	0.00
9	2	0.9260	0.00
9	3	0.8953	0.00
9	4	0.8388	0.00
9	5	0.8018	0.00
9	6	0.7781	0.00
9	7	0.7153	0.00
9	8	0.6734	1.00
9	9	0.6218	1.00
9	10	0.5579	2.00
9	11	0.4793	4.00
9	12	0.3842	7.00
9	13	0.2745	15.00
9	14	0.2178	24.00
9	15	0.1659	38.00
9	16	0.1308	63.00
9	17	0.1307	96.00
9	18	0.1651	122.00
9	19	0.2127	136.00
9	20	0.2530	142.00
9	21	0.2645	145.00
9	22	0.2274	146.00
9	23	0.1448	151.00
9	24	0.6526E-01	-177.00
9	25	0.4884E-01	-109.00
9	26	0.4316E-01	-64.00
9	27	0.2450E-01	-18.00
9	28	0.8057E-02	96.00
9	29	0.8214E-02	-169.00
9	30	0.8331E-03	-175.00
9	31	0.2224E-03	133.00

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HFTRANSFER FUNCTION ROLL

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'idir	ifreq	ampl	phase
1	1	0.000	0.00
1	2	0.000	0.00
1	3	0.000	0.00
1	4	0.000	0.00
1	5	0.000	0.00
1	6	0.000	0.00
1	7	0.000	0.00
1	8	0.000	0.00
1	9	0.000	0.00
1	10	0.000	0.00
1	11	0.000	0.00
1	12	0.000	0.00
1	13	0.000	0.00
1	14	0.000	0.00

1	15	0.000	0.00
1	16	0.000	0.00
1	17	0.000	0.00
1	18	0.000	0.00
1	19	0.000	0.00
1	20	0.000	0.00
1	21	0.000	0.00
1	22	0.000	0.00
1	23	0.000	0.00
1	24	0.000	0.00
1	25	0.000	0.00
1	26	0.000	0.00
1	27	0.000	0.00
1	28	0.000	0.00
1	29	0.000	0.00
1	30	0.000	0.00
1	31	0.000	0.00
2	1	0.5421	-93.00
2	2	0.5584	-94.00
2	3	0.5878	-95.00
2	4	0.6537	-96.00
2	5	0.7084	-97.00
2	6	0.7500	-98.00
2	7	0.8984	-101.00
2	8	1.048	-105.00
2	9	1.340	-111.00
2	10	2.047	-131.00
2	11	2.322	163.00
2	12	0.8816	123.00
2	13	0.3591	116.00
2	14	0.2301	117.00
2	15	0.1425	123.00
2	16	0.8331E-01	136.00
2	17	0.5046E-01	165.00
2	18	0.4659E-01	-155.00
2	19	0.5646E-01	-133.00
2	20	0.6367E-01	-124.00
2	21	0.6317E-01	-119.00
2	22	0.5517E-01	-116.00
2	23	0.4239E-01	-110.00
2	24	0.2702E-01	-100.00
2	25	0.1292E-01	-66.00
2	26	0.1133E-01	-2.00
2	27	0.1205E-01	29.00
2	28	0.5910E-02	48.00
2	29	0.2383E-02	-170.00
2	30	0.6068E-03	67.00
2	31	0.1319E-03	-103.00
3	1	0.9591	-93.00
3	2	0.9953	-93.00

3	3	1.061	-94.00
3	4	1.209	-96.00
3	5	1.332	-97.00
3	6	1.426	-98.00
3	7	1.760	-101.00
3	8	2.099	-105.00
3	9	2.763	-112.00
3	10	4.390	-132.00
3	11	5.266	161.00
3	12	2.178	120.00
3	13	1.021	110.00
3	14	0.7301	108.00
3	15	0.5261	107.00
3	16	0.3771	108.00
3	17	0.2654	110.00
3	18	0.1806	114.00
3	19	0.1177	123.00
3	20	0.7548E-01	139.00
3	21	0.5460E-01	165.00
3	22	0.4852E-01	-170.00
3	23	0.4531E-01	-151.00
3	24	0.4093E-01	-136.00
3	25	0.3534E-01	-123.00
3	26	0.2646E-01	-110.00
3	27	0.1759E-01	-89.00
3	28	0.9665E-02	-61.00
3	29	0.4032E-02	6.00
3	30	0.1943E-02	134.00
3	31	0.2468E-03	102.00
4	1	1.119	-92.00
4	2	1.166	-93.00
4	3	1.251	-93.00
4	4	1.441	-95.00
4	5	1.600	-96.00
4	6	1.722	-97.00
4	7	2.155	-101.00
4	8	2.595	-104.00
4	9	3.459	-111.00
4	10	5.586	-132.00
4	11	6.853	161.00
4	12	2.926	119.00
4	13	1.440	108.00
4	14	1.064	105.00
4	15	0.8011	104.00
4	16	0.6087	103.00
4	17	0.4637	102.00
4	18	0.3519	102.00
4	19	0.2643	102.00
4	20	0.1948	103.00
4	21	0.1397	105.00

4	22	0.9652E-01	107.00
4	23	0.6389E-01	111.00
4	24	0.4034E-01	117.00
4	25	0.2320E-01	124.00
4	26	0.1036E-01	135.00
4	27	0.3312E-02	178.00
4	28	0.2208E-02	-84.00
4	29	0.3464E-02	-36.00
4	30	0.2797E-02	44.00
4	31	0.1320E-02	162.00
5	1	0.9591	-92.00
5	2	0.9954	-92.00
5	3	1.061	-93.00
5	4	1.209	-94.00
5	5	1.332	-96.00
5	6	1.426	-97.00
5	7	1.760	-100.00
5	8	2.098	-104.00
5	9	2.762	-111.00
5	10	4.387	-132.00
5	11	5.260	160.00
5	12	2.174	118.00
5	13	1.018	105.00
5	14	0.7265	101.00
5	15	0.5226	98.00
5	16	0.3739	95.00
5	17	0.2624	91.00
5	18	0.1776	87.00
5	19	0.1132	80.00
5	20	0.6628E-01	68.00
5	21	0.3636E-01	45.00
5	22	0.2528E-01	4.00
5	23	0.2669E-01	-26.00
5	24	0.2893E-01	-38.00
5	25	0.2825E-01	-43.00
5	26	0.2416E-01	-46.00
5	27	0.1746E-01	-51.00
5	28	0.1070E-01	-59.00
5	29	0.5972E-02	-76.00
5	30	0.1460E-02	-156.00
5	31	0.1433E-03	132.00
6	1	0.7748	-91.00
6	2	0.8011	-92.00
6	3	0.8488	-93.00
6	4	0.9556	-94.00
6	5	1.044	-96.00
6	6	1.112	-97.00
6	7	1.353	-100.00
6	8	1.596	-104.00
6	9	2.072	-111.00

6	10	3.230	-132.00
6	11	3.773	159.00
6	12	1.500	116.00
6	13	0.6607	101.00
6	14	0.4510	96.00
6	15	0.3055	91.00
6	16	0.2013	84.00
6	17	0.1266	72.00
6	18	0.7642E-01	52.00
6	19	0.5237E-01	16.00
6	20	0.5172E-01	-20.00
6	21	0.5767E-01	-41.00
6	22	0.5952E-01	-53.00
6	23	0.5500E-01	-61.00
6	24	0.4486E-01	-67.00
6	25	0.3118E-01	-74.00
6	26	0.1737E-01	-85.00
6	27	0.7766E-02	-121.00
6	28	0.6669E-02	-179.00
6	29	0.5715E-02	163.00
6	30	0.8955E-03	20.00
6	31	0.1375E-03	65.00
7	1	0.5421	-91.00
7	2	0.5584	-92.00
7	3	0.5878	-92.00
7	4	0.6537	-94.00
7	5	0.7083	-95.00
7	6	0.7500	-96.00
7	7	0.8982	-100.00
7	8	1.048	-104.00
7	9	1.340	-112.00
7	10	2.045	-133.00
7	11	2.318	158.00
7	12	0.8798	113.00
7	13	0.3589	96.00
7	14	0.2312	88.00
7	15	0.1455	77.00
7	16	0.8931E-01	59.00
7	17	0.5965E-01	29.00
7	18	0.5466E-01	-7.00
7	19	0.6106E-01	-31.00
7	20	0.6640E-01	-46.00
7	21	0.6628E-01	-55.00
7	22	0.5997E-01	-63.00
7	23	0.4819E-01	-72.00
7	24	0.3277E-01	-85.00
7	25	0.1791E-01	-113.00
7	26	0.1218E-01	-171.00
7	27	0.1242E-01	152.00
7	28	0.7301E-02	141.00

7	29	0.3000E-03	57.00
7	30	0.5634E-03	144.00
7	31	0.1639E-03	-7.00
8	1	0.2784	-91.00
8	2	0.2860	-91.00
8	3	0.2996	-92.00
8	4	0.3302	-94.00
8	5	0.3555	-95.00
8	6	0.3747	-96.00
8	7	0.4434	-100.00
8	8	0.5125	-104.00
8	9	0.6476	-112.00
8	10	0.9720	-134.00
8	11	1.074	157.00
8	12	0.3916	111.00
8	13	0.1492	90.00
8	14	0.9171E-01	78.00
8	15	0.5583E-01	60.00
8	16	0.3770E-01	29.00
8	17	0.3483E-01	-6.00
8	18	0.3876E-01	-29.00
8	19	0.4230E-01	-43.00
8	20	0.4280E-01	-52.00
8	21	0.3967E-01	-60.00
8	22	0.3320E-01	-68.00
8	23	0.2427E-01	-79.00
8	24	0.1488E-01	-103.00
8	25	0.9843E-02	-153.00
8	26	0.1042E-01	163.00
8	27	0.8144E-02	142.00
8	28	0.2155E-02	114.00
8	29	0.1965E-02	-5.00
8	30	0.5457E-03	-86.00
8	31	0.6370E-04	147.00
9	1	0.9377E-07	89.00
9	2	0.9621E-07	89.00
9	3	0.1006E-06	88.00
9	4	0.1105E-06	86.00
9	5	0.1187E-06	85.00
9	6	0.1249E-06	84.00
9	7	0.1471E-06	80.00
9	8	0.1695E-06	76.00
9	9	0.2132E-06	68.00
9	10	0.3178E-06	46.00
9	11	0.3477E-06	-24.00
9	12	0.1247E-06	-70.00
9	13	0.4624E-07	-92.00
9	14	0.2800E-07	-107.00
9	15	0.1721E-07	-129.00
9	16	0.1275E-07	-163.00

9	17	0.1293E-07	166.00
9	18	0.1446E-07	146.00
9	19	0.1543E-07	135.00
9	20	0.1523E-07	126.00
9	21	0.1377E-07	119.00
9	22	0.1120E-07	110.00
9	23	0.7901E-08	97.00
9	24	0.4764E-08	69.00
9	25	0.3648E-08	16.00
9	26	0.3917E-08	-21.00
9	27	0.2709E-08	-40.00
9	28	0.5550E-09	-90.00
9	29	0.7696E-09	-179.00
9	30	0.2284E-09	100.00
9	31	0.1713E-10	90.00

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HFTRANSFER FUNCTION PITCH

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'idir	ifreq	ampl	phase
1	1	0.9691	90.00
1	2	0.9586	90.00
1	3	0.9415	90.00
1	4	0.9105	90.00
1	5	0.8904	90.00
1	6	0.8776	90.00
1	7	0.8437	90.00
1	8	0.8209	90.00
1	9	0.7924	90.00
1	10	0.7559	90.00
1	11	0.7080	90.00
1	12	0.6437	89.00
1	13	0.5554	89.00
1	14	0.4996	89.00
1	15	0.4354	89.00
1	16	0.3630	90.00
1	17	0.2847	93.00
1	18	0.2049	99.00
1	19	0.1327	114.00
1	20	0.9083E-01	149.00
1	21	0.1005	-175.00
1	22	0.1147	-162.00
1	23	0.9529E-01	-156.00
1	24	0.5500E-01	-142.00
1	25	0.2608E-01	-98.00
1	26	0.1720E-01	-42.00
1	27	0.7163E-02	16.00
1	28	0.3848E-02	136.00
1	29	0.1942E-02	-97.00
1	30	0.8257E-03	-89.00
1	31	0.2752E-03	-159.00

2	1	0.8469	90.00
2	2	0.8404	90.00
2	3	0.8298	90.00
2	4	0.8105	90.00
2	5	0.7979	90.00
2	6	0.7899	90.00
2	7	0.7688	90.00
2	8	0.7545	90.00
2	9	0.7367	90.00
2	10	0.7137	90.00
2	11	0.6834	90.00
2	12	0.6420	90.00
2	13	0.5836	89.00
2	14	0.5457	89.00
2	15	0.5007	89.00
2	16	0.4482	89.00
2	17	0.3883	90.00
2	18	0.3220	91.00
2	19	0.2504	93.00
2	20	0.1753	99.00
2	21	0.1054	115.00
2	22	0.7520E-01	156.00
2	23	0.8438E-01	-175.00
2	24	0.7652E-01	-164.00
2	25	0.4807E-01	-151.00
2	26	0.1991E-01	-114.00
2	27	0.1204E-01	-37.00
2	28	0.6190E-02	20.00
2	29	0.2748E-02	147.00
2	30	0.8215E-03	109.00
2	31	0.2292E-03	-36.00
3	1	0.4978	90.00
3	2	0.4971	90.00
3	3	0.4959	90.00
3	4	0.4939	90.00
3	5	0.4927	90.00
3	6	0.4920	90.00
3	7	0.4903	90.00
3	8	0.4892	91.00
3	9	0.4880	91.00
3	10	0.4866	91.00
3	11	0.4850	91.00
3	12	0.4828	90.00
3	13	0.4793	90.00
3	14	0.4766	90.00
3	15	0.4730	89.00
3	16	0.4681	88.00
3	17	0.4619	87.00
3	18	0.4543	86.00
3	19	0.4443	83.00

3	20	0.4278	79.00
3	21	0.3922	71.00
3	22	0.3210	62.00
3	23	0.2209	54.00
3	24	0.1271	53.00
3	25	0.6223E-01	66.00
3	26	0.3037E-01	103.00
3	27	0.2210E-01	152.00
3	28	0.1639E-01	-172.00
3	29	0.8535E-02	-126.00
3	30	0.2172E-02	54.00
3	31	0.3640E-03	37.00
4	1	0.1671E-02	-174.00
4	2	0.2129E-02	-175.00
4	3	0.2797E-02	-176.00
4	4	0.3914E-02	-177.00
4	5	0.4618E-02	-178.00
4	6	0.5066E-02	-179.00
4	7	0.6265E-02	179.00
4	8	0.7088E-02	178.00
4	9	0.8140E-02	177.00
4	10	0.9524E-02	175.00
4	11	0.1140E-01	172.00
4	12	0.1402E-01	169.00
4	13	0.1786E-01	164.00
4	14	0.2047E-01	160.00
4	15	0.2376E-01	156.00
4	16	0.2801E-01	152.00
4	17	0.3367E-01	146.00
4	18	0.4142E-01	138.00
4	19	0.5212E-01	127.00
4	20	0.6622E-01	111.00
4	21	0.8136E-01	89.00
4	22	0.8915E-01	60.00
4	23	0.8122E-01	29.00
4	24	0.6210E-01	2.00
4	25	0.4234E-01	-19.00
4	26	0.2695E-01	-33.00
4	27	0.1626E-01	-41.00
4	28	0.9351E-02	-40.00
4	29	0.5299E-02	-32.00
4	30	0.1499E-02	13.00
4	31	0.3738E-03	113.00
5	1	0.4981	-90.00
5	2	0.4974	-90.00
5	3	0.4962	-90.00
5	4	0.4941	-90.00
5	5	0.4928	-90.00
5	6	0.4919	-90.00
5	7	0.4897	-91.00

5	8	0.4881	-91.00
5	9	0.4862	-91.00
5	10	0.4837	-91.00
5	11	0.4802	-92.00
5	12	0.4751	-92.00
5	13	0.4669	-93.00
5	14	0.4610	-94.00
5	15	0.4533	-95.00
5	16	0.4436	-96.00
5	17	0.4313	-98.00
5	18	0.4163	-100.00
5	19	0.3974	-103.00
5	20	0.3718	-107.00
5	21	0.3331	-113.00
5	22	0.2735	-122.00
5	23	0.1952	-131.00
5	24	0.1160	-139.00
5	25	0.5328E-01	-140.00
5	26	0.1459E-01	-126.00
5	27	0.5907E-02	-8.00
5	28	0.7413E-02	35.00
5	29	0.4417E-02	77.00
5	30	0.6451E-03	-68.00
5	31	0.1319E-03	-91.00
6	1	0.6981	-90.00
6	2	0.6949	-90.00
6	3	0.6897	-90.00
6	4	0.6801	-90.00
6	5	0.6738	-90.00
6	6	0.6697	-90.00
6	7	0.6589	-90.00
6	8	0.6515	-90.00
6	9	0.6422	-91.00
6	10	0.6299	-91.00
6	11	0.6135	-91.00
6	12	0.5905	-92.00
6	13	0.5574	-93.00
6	14	0.5354	-93.00
6	15	0.5090	-94.00
6	16	0.4775	-94.00
6	17	0.4409	-95.00
6	18	0.3992	-96.00
6	19	0.3526	-97.00
6	20	0.2997	-99.00
6	21	0.2367	-102.00
6	22	0.1596	-107.00
6	23	0.7777E-01	-110.00
6	24	0.2079E-01	-73.00
6	25	0.2463E-01	9.00
6	26	0.2367E-01	27.00

6	27	0.1262E-01	54.00
6	28	0.4835E-02	115.00
6	29	0.2149E-02	-140.00
6	30	0.5513E-03	113.00
6	31	0.8135E-04	-159.00
7	1	0.8472	-90.00
7	2	0.8407	-90.00
7	3	0.8300	-90.00
7	4	0.8105	-90.00
7	5	0.7976	-90.00
7	6	0.7894	-90.00
7	7	0.7674	-90.00
7	8	0.7524	-90.00
7	9	0.7335	-90.00
7	10	0.7090	-91.00
7	11	0.6765	-91.00
7	12	0.6321	-91.00
7	13	0.5703	-92.00
7	14	0.5308	-92.00
7	15	0.4847	-92.00
7	16	0.4319	-92.00
7	17	0.3733	-92.00
7	18	0.3104	-90.00
7	19	0.2457	-88.00
7	20	0.1812	-83.00
7	21	0.1191	-75.00
7	22	0.6635E-01	-54.00
7	23	0.4688E-01	-8.00
7	24	0.4807E-01	21.00
7	25	0.3552E-01	38.00
7	26	0.1737E-01	69.00
7	27	0.7652E-02	133.00
7	28	0.4234E-02	-134.00
7	29	0.2852E-02	-55.00
7	30	0.4499E-03	-111.00
7	31	0.3961E-04	104.00
8	1	0.9387	-90.00
8	2	0.9293	-90.00
8	3	0.9140	-90.00
8	4	0.8860	-90.00
8	5	0.8676	-90.00
8	6	0.8559	-90.00
8	7	0.8246	-90.00
8	8	0.8034	-90.00
8	9	0.7767	-90.00
8	10	0.7423	-90.00
8	11	0.6971	-91.00
8	12	0.6363	-91.00
8	13	0.5535	-92.00
8	14	0.5018	-92.00

8	15	0.4427	-91.00
8	16	0.3768	-90.00
8	17	0.3061	-88.00
8	18	0.2343	-84.00
8	19	0.1670	-75.00
8	20	0.1121	-58.00
8	21	0.8104E-01	-28.00
8	22	0.7519E-01	2.00
8	23	0.7085E-01	21.00
8	24	0.5173E-01	36.00
8	25	0.2731E-01	63.00
8	26	0.1326E-01	119.00
8	27	0.7936E-02	-169.00
8	28	0.4899E-02	-92.00
8	29	0.1689E-02	12.00
8	30	0.2806E-03	-11.00
8	31	0.2694E-04	-124.00
9	1	0.9694	-90.00
9	2	0.9589	-90.00
9	3	0.9418	-90.00
9	4	0.9105	-90.00
9	5	0.8900	-90.00
9	6	0.8769	-90.00
9	7	0.8421	-90.00
9	8	0.8184	-90.00
9	9	0.7887	-90.00
9	10	0.7506	-90.00
9	11	0.7007	-91.00
9	12	0.6339	-91.00
9	13	0.5436	-91.00
9	14	0.4877	-91.00
9	15	0.4242	-91.00
9	16	0.3542	-90.00
9	17	0.2802	-87.00
9	18	0.2070	-81.00
9	19	0.1419	-68.00
9	20	0.9676E-01	-44.00
9	21	0.8297E-01	-10.00
9	22	0.8502E-01	14.00
9	23	0.7529E-01	27.00
9	24	0.4926E-01	42.00
9	25	0.2423E-01	76.00
9	26	0.1307E-01	138.00
9	27	0.8450E-02	-152.00
9	28	0.4596E-02	-82.00
9	29	0.1774E-02	44.00
9	30	0.3288E-03	22.00
9	31	0.1730E-04	-73.00

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HFTRANSFER FUNCTION YAW

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'idir	ifreq	ampl	phase
1	1	0.000	0.00
1	2	0.000	0.00
1	3	0.000	0.00
1	4	0.000	0.00
1	5	0.000	0.00
1	6	0.000	0.00
1	7	0.000	0.00
1	8	0.000	0.00
1	9	0.000	0.00
1	10	0.000	0.00
1	11	0.000	0.00
1	12	0.000	0.00
1	13	0.000	0.00
1	14	0.000	0.00
1	15	0.000	0.00
1	16	0.000	0.00
1	17	0.000	0.00
1	18	0.000	0.00
1	19	0.000	0.00
1	20	0.000	0.00
1	21	0.000	0.00
1	22	0.000	0.00
1	23	0.000	0.00
1	24	0.000	0.00
1	25	0.000	0.00
1	26	0.000	0.00
1	27	0.000	0.00
1	28	0.000	0.00
1	29	0.000	0.00
1	30	0.000	0.00
1	31	0.000	0.00
2	1	0.7894	178.00
2	2	0.6890	178.00
2	3	0.5879	178.00
2	4	0.4848	178.00
2	5	0.4424	177.00
2	6	0.4207	177.00
2	7	0.3756	177.00
2	8	0.3517	176.00
2	9	0.3256	176.00
2	10	0.2932	175.00
2	11	0.2568	178.00
2	12	0.2395	178.00
2	13	0.2070	177.00
2	14	0.1879	176.00
2	15	0.1672	176.00
2	16	0.1449	175.00
2	17	0.1211	174.00

2	18	0.9604E-01	173.00
2	19	0.7025E-01	170.00
2	20	0.4466E-01	165.00
2	21	0.2137E-01	149.00
2	22	0.9160E-02	76.00
2	23	0.1613E-01	22.00
2	24	0.1796E-01	13.00
2	25	0.1137E-01	17.00
2	26	0.3467E-02	83.00
2	27	0.5271E-02	160.00
2	28	0.2873E-02	-134.00
2	29	0.2466E-02	-49.00
2	30	0.7243E-03	-83.00
2	31	0.1792E-03	100.00
3	1	0.8035	178.00
3	2	0.7056	178.00
3	3	0.6080	178.00
3	4	0.5108	178.00
3	5	0.4718	178.00
3	6	0.4522	177.00
3	7	0.4123	177.00
3	8	0.3914	176.00
3	9	0.3679	175.00
3	10	0.3330	174.00
3	11	0.2930	-179.00
3	12	0.3013	-179.00
3	13	0.2820	-180.00
3	14	0.2691	179.00
3	15	0.2547	179.00
3	16	0.2387	179.00
3	17	0.2210	179.00
3	18	0.2015	179.00
3	19	0.1799	179.00
3	20	0.1562	179.00
3	21	0.1301	-180.00
3	22	0.1021	-179.00
3	23	0.7327E-01	-177.00
3	24	0.4595E-01	-172.00
3	25	0.2217E-01	-163.00
3	26	0.5599E-02	-115.00
3	27	0.7738E-02	-10.00
3	28	0.8637E-02	21.00
3	29	0.5280E-02	72.00
3	30	0.1654E-02	-101.00
3	31	0.4401E-03	-128.00
4	1	0.2660E-01	89.00
4	2	0.2147E-01	89.00
4	3	0.1739E-01	88.00
4	4	0.1491E-01	87.00
4	5	0.1479E-01	85.00

4	6	0.1512E-01	84.00
4	7	0.1739E-01	80.00
4	8	0.2036E-01	76.00
4	9	0.2677E-01	69.00
4	10	0.4346E-01	48.00
4	11	0.5497E-01	-20.00
4	12	0.2496E-01	-63.00
4	13	0.1356E-01	-76.00
4	14	0.1070E-01	-80.00
4	15	0.8685E-02	-83.00
4	16	0.7187E-02	-86.00
4	17	0.6011E-02	-89.00
4	18	0.5034E-02	-92.00
4	19	0.4170E-02	-95.00
4	20	0.3365E-02	-99.00
4	21	0.2602E-02	-101.00
4	22	0.1915E-02	-101.00
4	23	0.1388E-02	-96.00
4	24	0.1106E-02	-86.00
4	25	0.9703E-03	-84.00
4	26	0.7125E-03	-94.00
4	27	0.4180E-03	-96.00
4	28	0.4035E-03	-117.00
4	29	0.3853E-03	-155.00
4	30	0.6166E-03	-170.00
4	31	0.4175E-03	-120.00
5	1	0.8040	2.00
5	2	0.7062	2.00
5	3	0.6089	2.00
5	4	0.5123	2.00
5	5	0.4740	2.00
5	6	0.4549	3.00
5	7	0.4173	3.00
5	8	0.3993	4.00
5	9	0.3835	4.00
5	10	0.3788	5.00
5	11	0.3722	-1.00
5	12	0.3179	-1.00
5	13	0.2866	0.00
5	14	0.2718	1.00
5	15	0.2562	2.00
5	16	0.2396	2.00
5	17	0.2217	3.00
5	18	0.2021	4.00
5	19	0.1808	5.00
5	20	0.1576	7.00
5	21	0.1323	9.00
5	22	0.1049	11.00
5	23	0.7658E-01	16.00
5	24	0.4940E-01	23.00

5	25	0.2581E-01	38.00
5	26	0.9805E-02	82.00
5	27	0.9119E-02	166.00
5	28	0.9577E-02	-156.00
5	29	0.4806E-02	-107.00
5	30	0.2271E-02	75.00
5	31	0.7365E-03	89.00
6	1	0.9200	2.00
6	2	0.8056	2.00
6	3	0.6911	2.00
6	4	0.5759	2.00
6	5	0.5294	2.00
6	6	0.5059	3.00
6	7	0.4586	3.00
6	8	0.4349	3.00
6	9	0.4123	4.00
6	10	0.3968	5.00
6	11	0.3775	1.00
6	12	0.3229	1.00
6	13	0.2832	2.00
6	14	0.2628	3.00
6	15	0.2410	3.00
6	16	0.2176	4.00
6	17	0.1924	5.00
6	18	0.1653	6.00
6	19	0.1363	7.00
6	20	0.1057	9.00
6	21	0.7405E-01	11.00
6	22	0.4299E-01	15.00
6	23	0.1644E-01	31.00
6	24	0.7017E-02	136.00
6	25	0.1359E-01	179.00
6	26	0.1202E-01	-161.00
6	27	0.5207E-02	-114.00
6	28	0.5611E-02	-12.00
6	29	0.3999E-02	35.00
6	30	0.9887E-03	-59.00
6	31	0.4518E-03	63.00
7	1	0.7896	2.00
7	2	0.6894	2.00
7	3	0.5884	2.00
7	4	0.4857	2.00
7	5	0.4436	3.00
7	6	0.4221	3.00
7	7	0.3782	3.00
7	8	0.3556	4.00
7	9	0.3333	4.00
7	10	0.3147	5.00
7	11	0.2917	1.00
7	12	0.2462	2.00

7	13	0.2087	3.00
7	14	0.1890	4.00
7	15	0.1680	5.00
7	16	0.1456	6.00
7	17	0.1220	7.00
7	18	0.9724E-01	8.00
7	19	0.7188E-01	9.00
7	20	0.4659E-01	11.00
7	21	0.2267E-01	15.00
7	22	0.3199E-02	53.00
7	23	0.1095E-01	179.00
7	24	0.1404E-01	-174.00
7	25	0.8415E-02	-162.00
7	26	0.3037E-02	-59.00
7	27	0.6162E-02	-7.00
7	28	0.2019E-02	35.00
7	29	0.2973E-02	-176.00
7	30	0.5806E-03	108.00
7	31	0.1516E-03	-35.00
8	1	0.4529	2.00
8	2	0.3945	2.00
8	3	0.3355	2.00
8	4	0.2750	2.00
8	5	0.2499	3.00
8	6	0.2371	3.00
8	7	0.2106	3.00
8	8	0.1969	4.00
8	9	0.1830	4.00
8	10	0.1705	5.00
8	11	0.1552	2.00
8	12	0.1293	3.00
8	13	0.1066	4.00
8	14	0.9459E-01	5.00
8	15	0.8192E-01	6.00
8	16	0.6861E-01	7.00
8	17	0.5480E-01	8.00
8	18	0.4076E-01	10.00
8	19	0.2689E-01	12.00
8	20	0.1384E-01	15.00
8	21	0.2666E-02	32.00
8	22	0.5606E-02	-177.00
8	23	0.8637E-02	-173.00
8	24	0.6291E-02	-168.00
8	25	0.1135E-02	-117.00
8	26	0.3825E-02	-7.00
8	27	0.2566E-02	0.00
8	28	0.1692E-02	-178.00
8	29	0.1015E-02	-162.00
8	30	0.4200E-03	-156.00
8	31	0.6886E-04	144.00

9	1	0.1580E-06	-178.00
9	2	0.1375E-06	-178.00
9	3	0.1168E-06	-178.00
9	4	0.9547E-07	-178.00
9	5	0.8663E-07	-177.00
9	6	0.8209E-07	-177.00
9	7	0.7269E-07	-177.00
9	8	0.6779E-07	-176.00
9	9	0.6281E-07	-176.00
9	10	0.5827E-07	-175.00
9	11	0.5270E-07	-178.00
9	12	0.4364E-07	-177.00
9	13	0.3560E-07	-176.00
9	14	0.3134E-07	-175.00
9	15	0.2687E-07	-174.00
9	16	0.2220E-07	-173.00
9	17	0.1738E-07	-171.00
9	18	0.1254E-07	-170.00
9	19	0.7844E-08	-167.00
9	20	0.3527E-08	-163.00
9	21	0.3371E-09	-64.00
9	22	0.2438E-08	6.00
9	23	0.2995E-08	9.00
9	24	0.1799E-08	14.00
9	25	0.3838E-09	137.00
9	26	0.1457E-08	177.00
9	27	0.6143E-09	179.00
9	28	0.7820E-09	8.00
9	29	0.1402E-09	22.00
9	30	0.7674E-10	43.00
9	31	0.3629E-10	16.00

END

STAMOD FILE (CASE1-BALLASTED-TENSION 15%MBL-H=15m , T=9s)

'
'---
'Static and Dynamic Response Analysis of mooring system

```
'-----------------------------------------------------------------------------
'mooring system: catenary
'depth: 100m
'floatar: suezmax vessel
'modeling: standard AR system
'element type: beam
'created by: Leila
'-----------------------------------------------------------------------------
STAMOD CONTROL INFORMATION 3.4
******************************
******************************
******************************
' irunco  chiris  ianal   iprdat  iprcat  iprfem  ipform  iprnor
   1      SYS     1       1       1       1       2     1
'-----------------------------------------------------------------------------
 RUN IDEN
' chires
 STATIC
'-----------------------------------------------------------------------------
 ENVI REFE IDEN
' idenv
 ENV
'-----------------------------------------------------------------------------
 STAT COND INPU
' nlcomp  icurin  curfac  lcons  isolvr
   0       1     1.000    1      2
'-----------------------------------------------------------------------------
 COMP PROC
' amet
 FEM
'-----------------------------------------------------------------------------
 FEM ANAL PARA
'-----------------------------------------------------------------------------
 LOAD GROUP DATA
' nstep     maxit      racu
   100    20        1.000E-09
' lotype     ispec
  VOLU
  DISP
  BEND
  FRIC
  CURR
'-----------------------------------------------------------------------------
 END
```

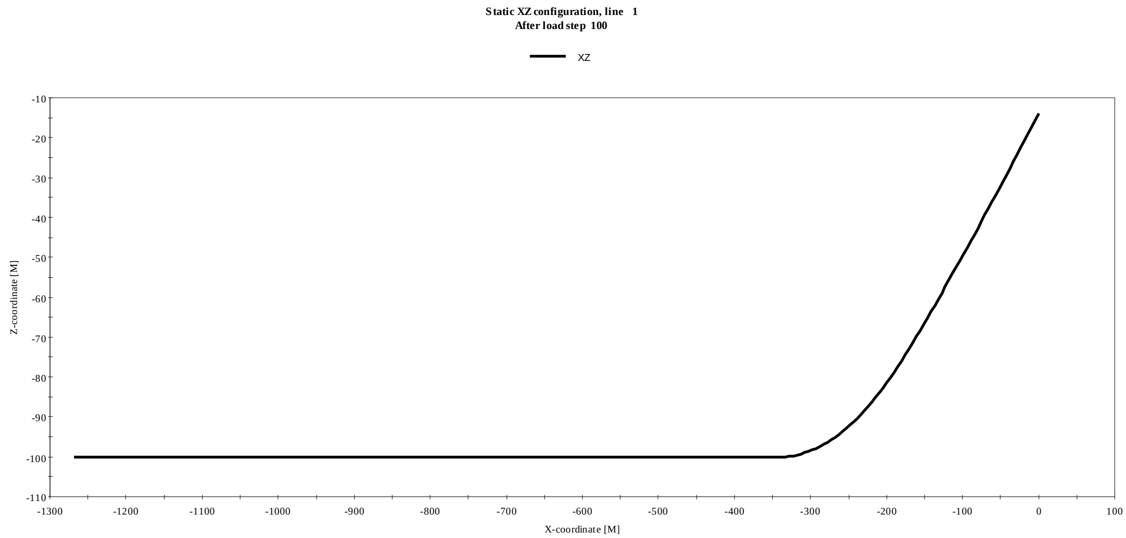
DYNMOD FILE (CASE1-BALLASTED-TENSION 15%MBL-H=15m , T=9s)

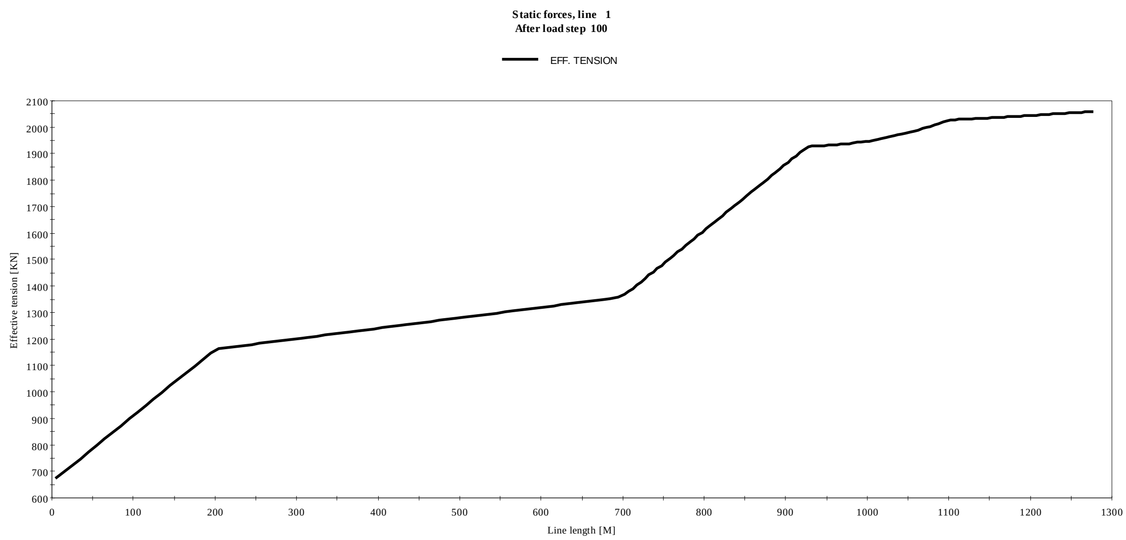
```
'
'-----------------------------------------------------------------------------
'Static and Dynamic Response Analysis of mooring system
'-----------------------------------------------------------------------------
'mooring system: catenary
'depth: 100m
'floatar: suezmax vessel
'modeling: standard AR system
'element type: beam
'created by: Leila
'-----------------------------------------------------------------------------
DYNMOD CONTROL INFORMATION  3.4
********************************
********************************
********************************
' irunco   ianal   idris   idenv   idstat   idirr   idres
  ANAL     REGU     SYS     ENV   STATIC     IRR     DYN
'-----------------------------------------------------------------------------
 REGU WAVE ANAL
' nper   nstppr   irwcn   imotd
   5     400      1       1
'-----------------------------------------------------------------------------
 REGU WAVE LOAD
' iwtyp   isurf   iuupos
  1       2      2
'-----------------------------------------------------------------------------
 REGW PRIN OPTI
' nprend   nprenf   nprenc
   1       1       1
'-----------------------------------------------------------------------------
 TIME DOMA PROC
' itdmet   inewil   idisst   iforst   icurst  istrst
   2       1       1       1       0       0
' betin  gamma  tetha  a1   a2   a1t  a1t0  a1b  a2t  a2t0  a2b
' Dynamic, period 9-17s:
 4.000   .500  1.000  .000  .057  .000  .000  .000  .000  .000  .000
' 4.000   .500  1.000  .000  .064  .000  .000  .000  .000  .000  .000
' 4.000   .500  1.000  .000  .070  .000  .000  .000  .000  .000  .000
' 4.000   .500  1.000  .000  .076  .000  .000  .000  .000  .000  .000
' 4.000   .500  1.000  .000  .083  .000  .000  .000  .000  .000  .000
' 4.000   .500  1.000  .000  .089  .000  .000  .000  .000  .000  .000
' 4.000   .500  1.000  .000  .095  .000  .000  .000  .000  .000  .000
' 4.000   .500  1.000  .000  .102  .000  .000  .000  .000  .000  .000
' 4.000   .500  1.000  .000  .108  .000  .000  .000  .000  .000  .000
' indint  indhyd  maxhit  epshyd  ntramp  indrel  iconre  istepr  ldamp
' Dynamic:
    1    1    -5    .01    18    0    0    0    0
'   1    1    -5    .01    20    0    0    0    0
'   1    1    -5    .01    22    0    0    0    0
'   1    1    -5    .01    24    0    0    0    0
```

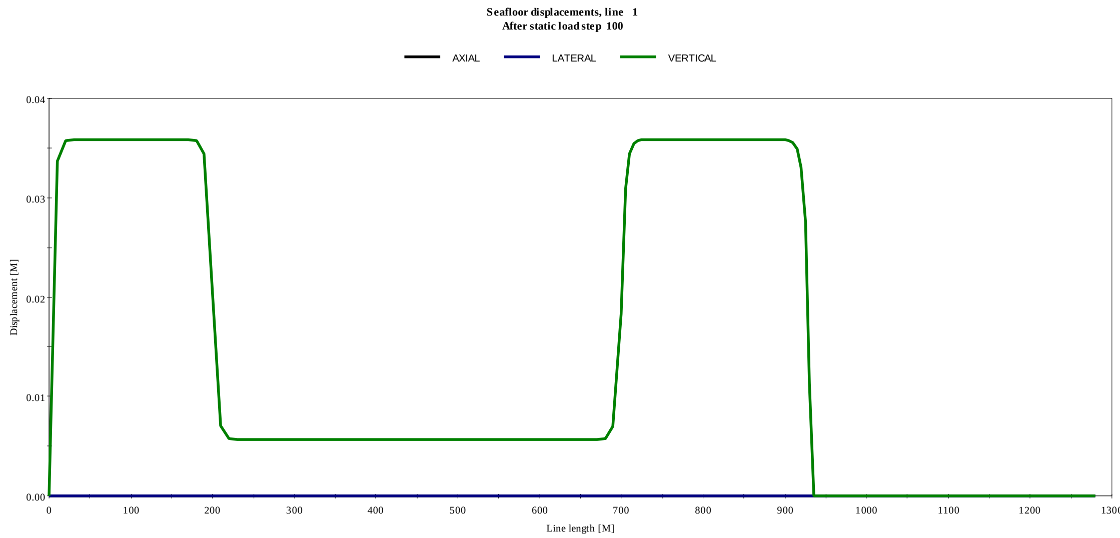
```
'   1    1   -5    .01   26    0    0    0    0
'   1    1   -5    .01   28    0    0    0    0
'   1    1   -5    .01   30    0    0    0    0
'   1    1   -5    .01   32    0    0    0    0
'   1    1   -5    .01   34    0    0    0    0
'-----------------------------------------------------------------------------
 NONL INTE PROC
' itfreq   isolit   maxit   daccu   icocod   ivarst    itstat
   1       1       20   1.0E-8    1       5        1
'-----------------------------------------------------------------------------
 DISP RESP STOR
' idisp   nodisp
   4     4
' ilin    iseg    chinod
   1       1      ALL
   1       2      ALL
   1       3      ALL
   1       4      ALL
'-----------------------------------------------------------------------------
 FORC RESP STOR
' iforc   noforc
   4     4
' ilin    iseg    chinod
   1       1      ALL
   1       2      ALL
   1       3      ALL
   1       4      ALL
'-----------------------------------------------------------------------------
 ENVE CURV SPEC
' ienvd   ienvf   ienvc   tenvs   tenve   nprend   nprenf   nprenc
'Dynamic:
    1    1    1     27.00     45.00    1    1    1
'   1    1    1    30.00     50.00    0    0    0
'   1    1    1    33.00     55.00    0    0    0
'   1    1    1    36.00     60.00    0    0    0
'   1    1    1    39.00     65.00    0    0    0
'   1    1    1    42.00     70.00    0    0    0
'   1    1    1    45.00     75.00    0    0    0
'   1    1    1    48.00     80.00    0    0    0
'   1    1    1    51.00     85.00    0    0    0
'-----------------------------------------------------------------------------
 END
```

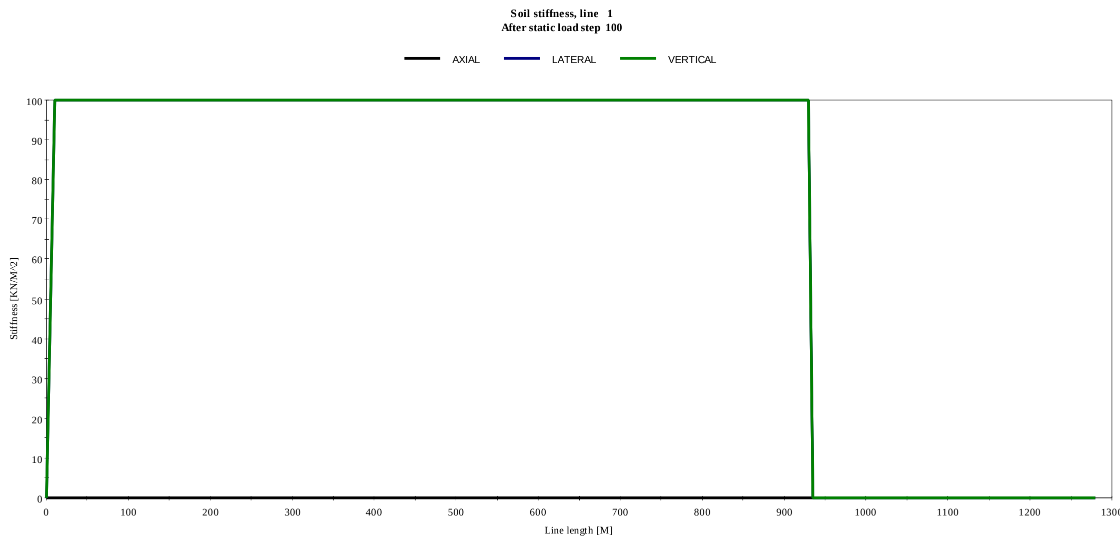
APPENDIX B

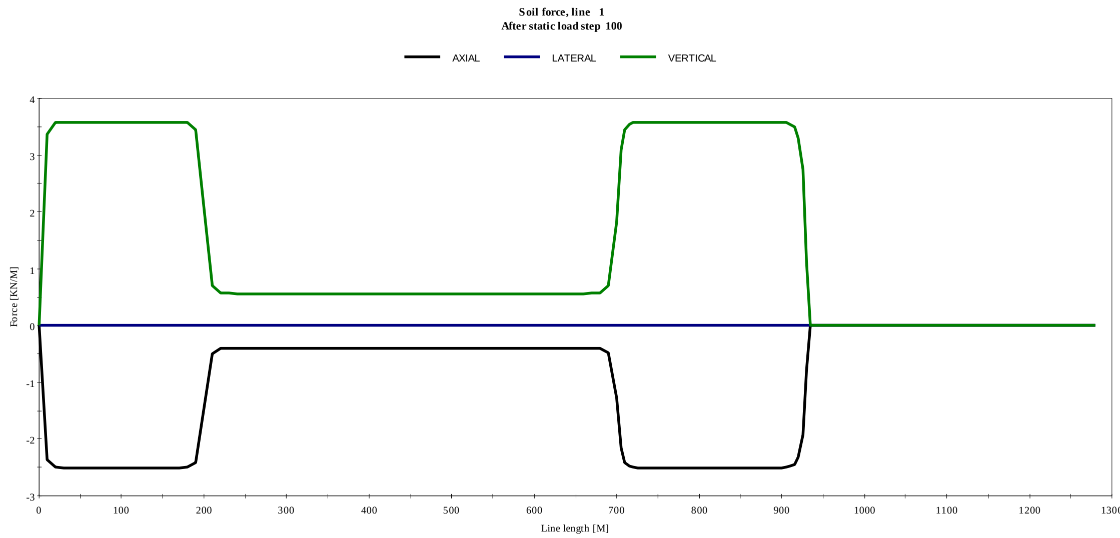
Case 1- water depth 100m
Ballasted – tension 15%MBL (2070KN) - H=15m, Period 9s

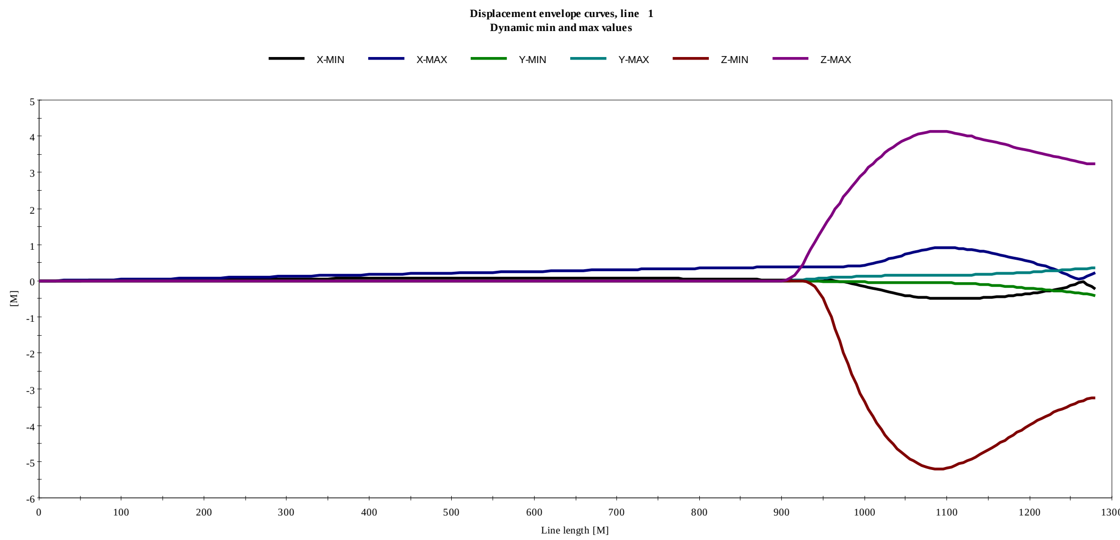


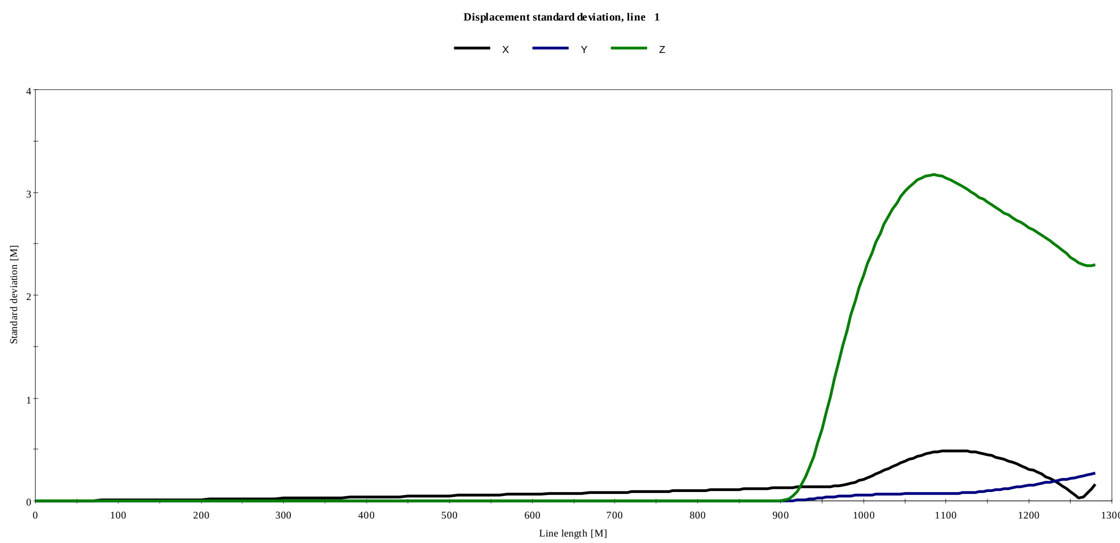


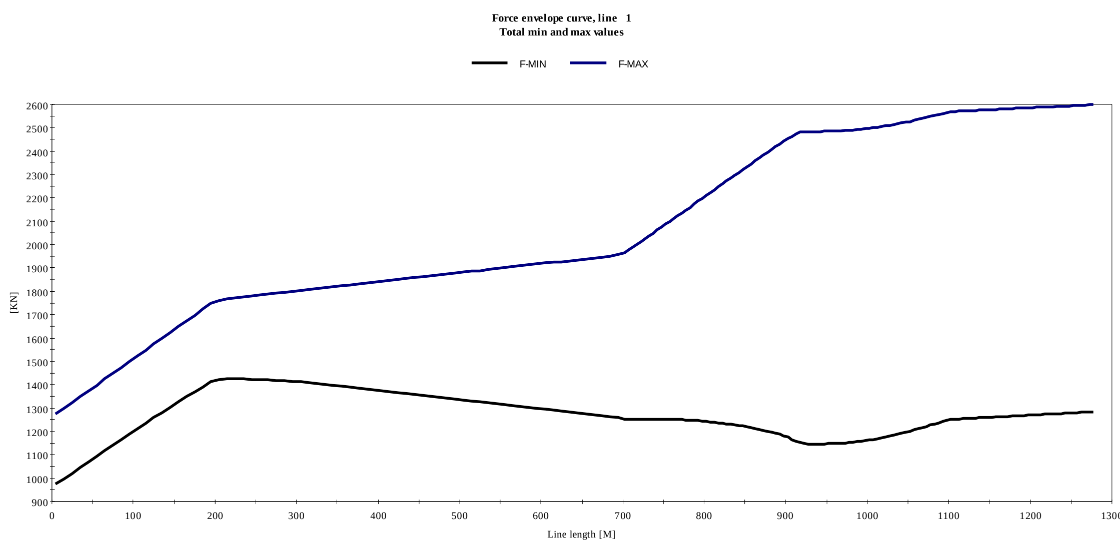

Seafloor displacements, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Displacement [M]
Line length [M]

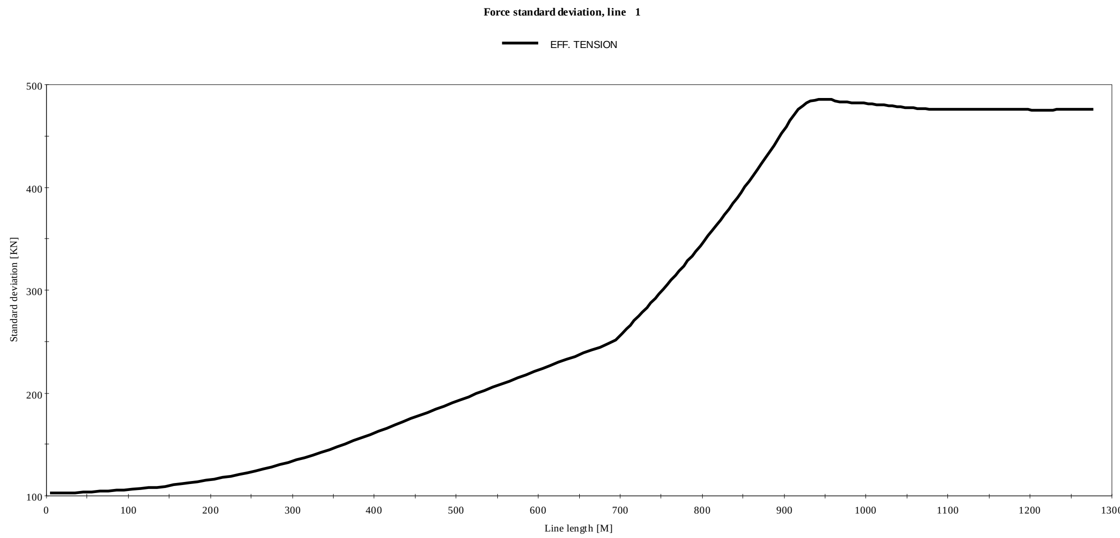

Soil stiffness, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Stiffness [KN/M^2]
Line length [M]


Soil force, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Force [KN/M]
Line length [M]

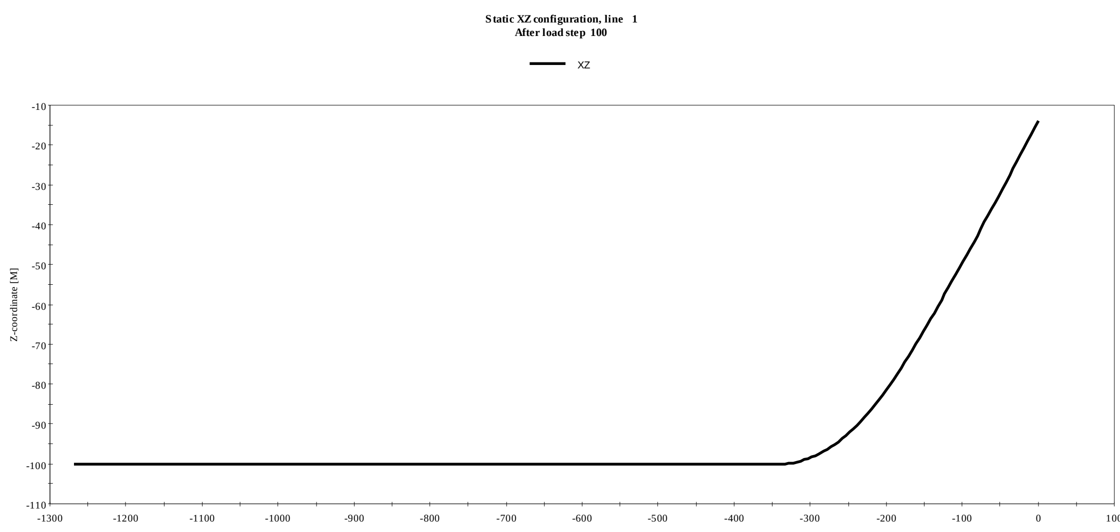

Displacement envelope curves, line 1
Dynamic min and max values
X-MIN
X-MAX
Y-MIN
Y-MAX
Z-MIN
Z-MAX
[M]
Line length [M]

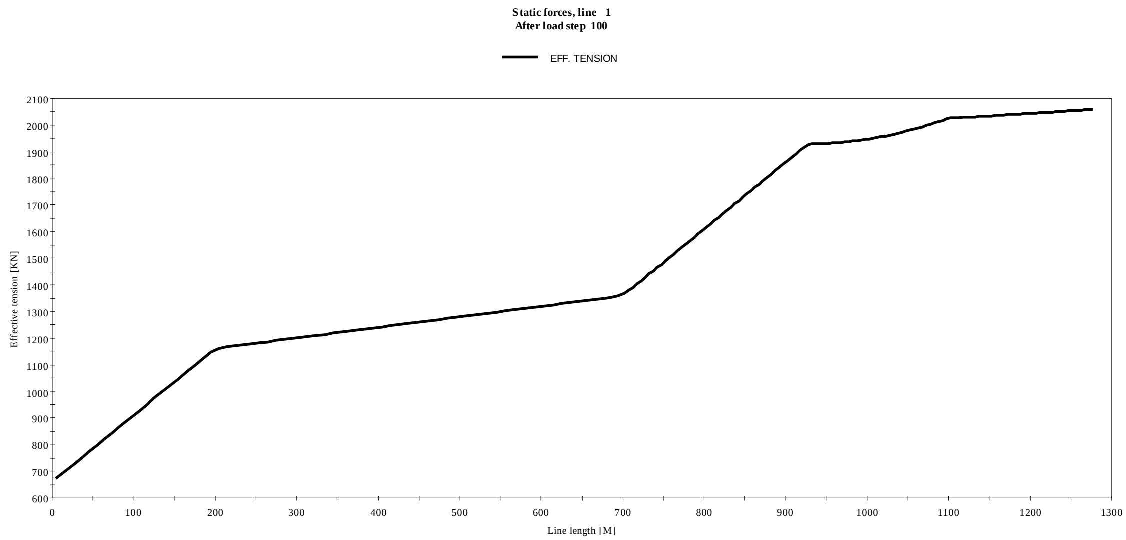

Displacement standard deviation, line 1
X
Y
Z
Standard deviation [M]
0
1
2
3
4
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
Line length [M]

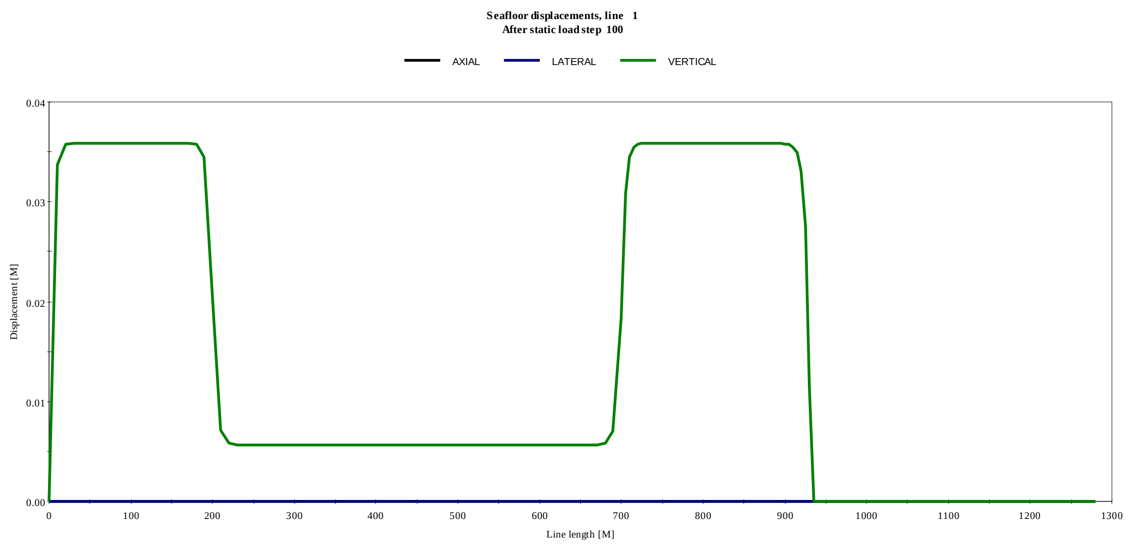

Force envelope curve, line 1
Total min and max values
F-MIN
F-MAX
[KN]
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
Line length [M]

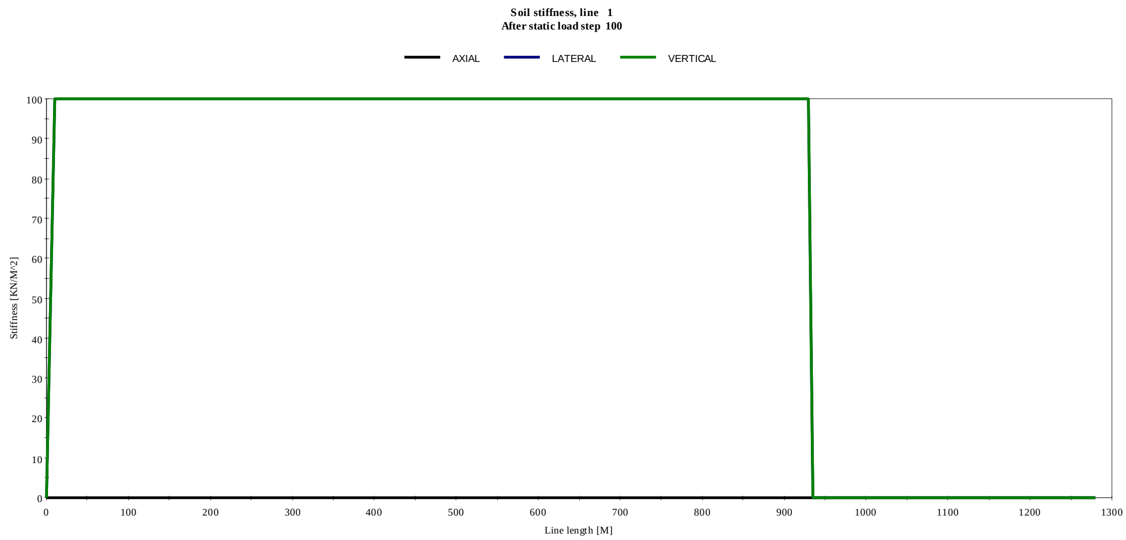


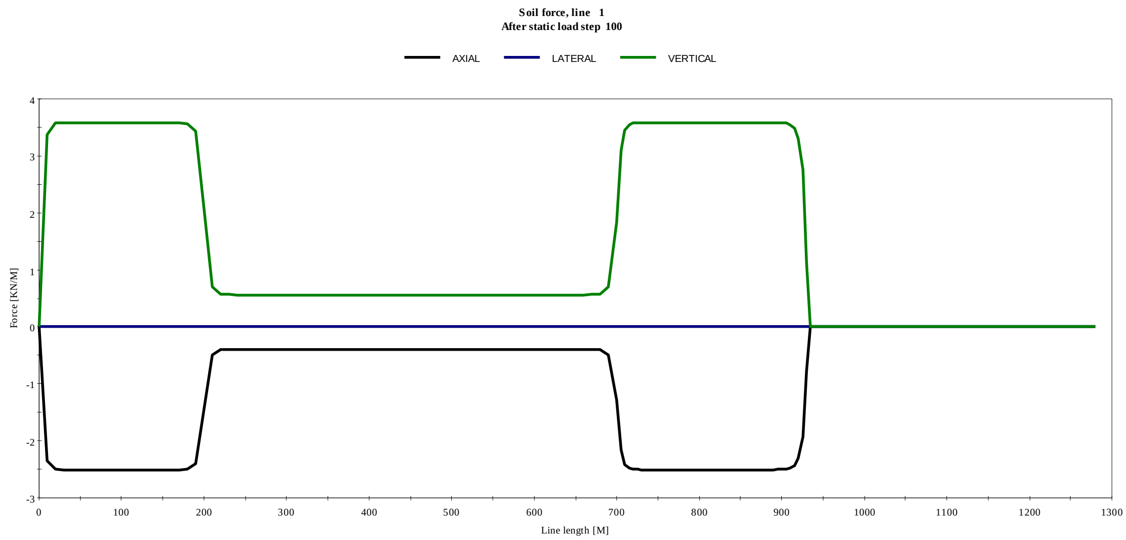
Case 1- water depth 100m
Ballasted – tension 15%MBL (2070KN) - H=15m, Period 10s

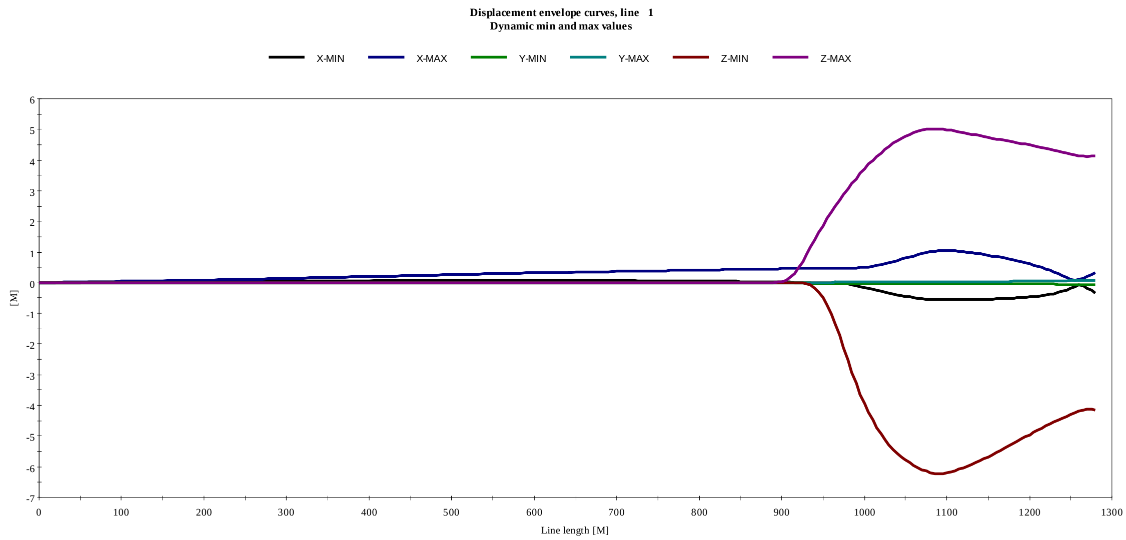


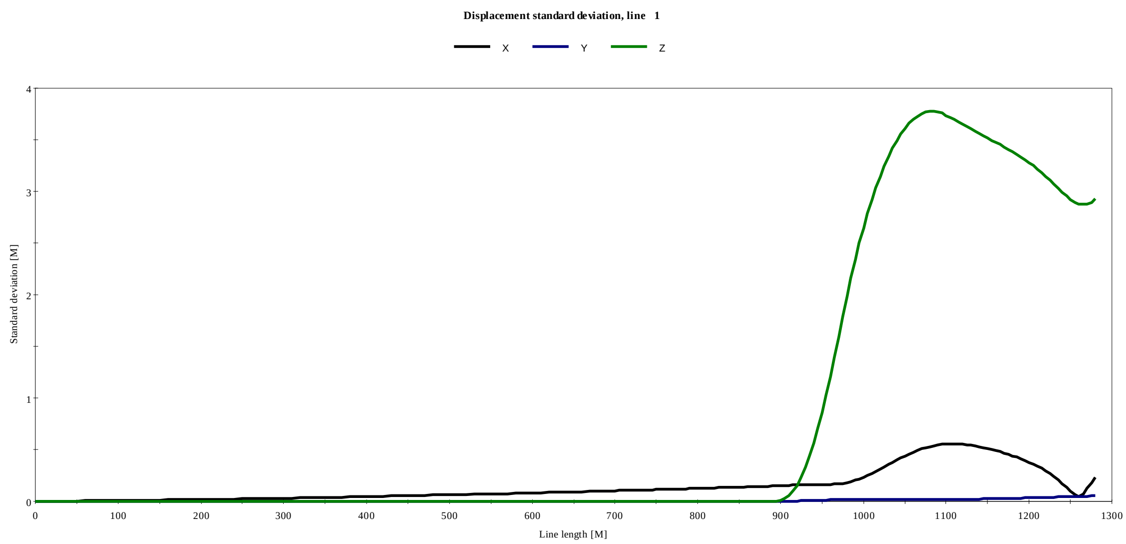

Static forces, line 1
After load step 100
EFF. TENSION
Effective tension [KN]
Line length [M]

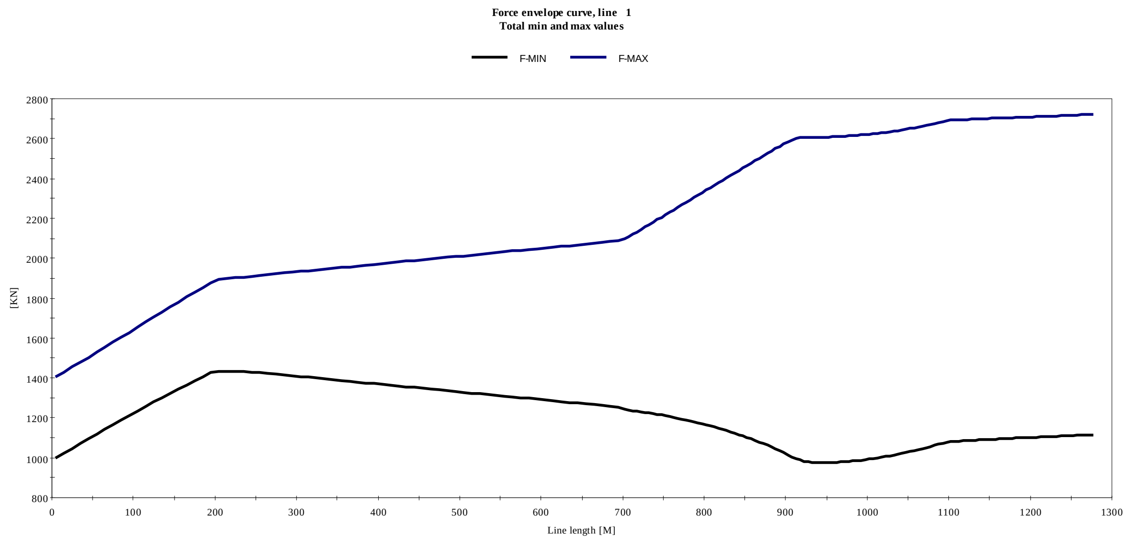

Seafloor displacements, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Displacement [M]
Line length [M]

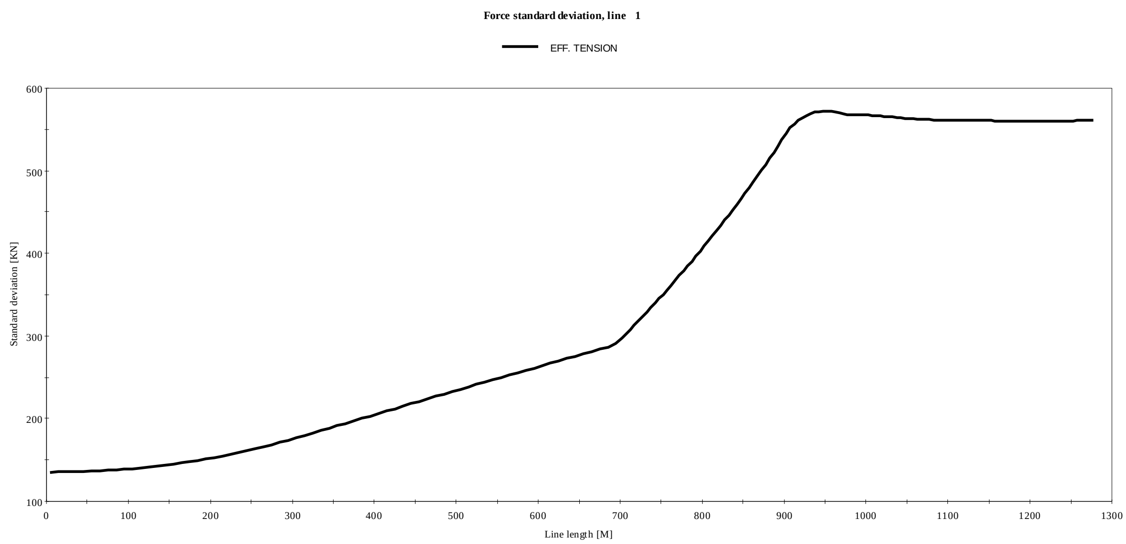

Soil stiffness, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Stiffness [KN/M^2]
Line length [M]


Soil force, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Force [KN/M]
Line length [M]

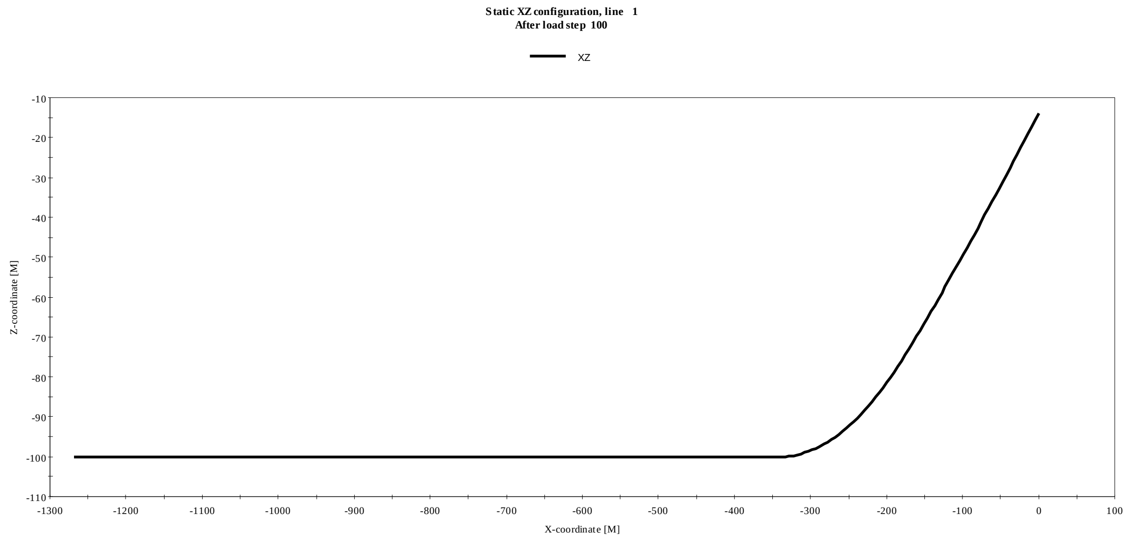

Displacement envelope curves, line 1
Dynamic min and max values
X-MIN
X-MAX
Y-MIN
Y-MAX
Z-MIN
Z-MAX
[M]
Line length [M]

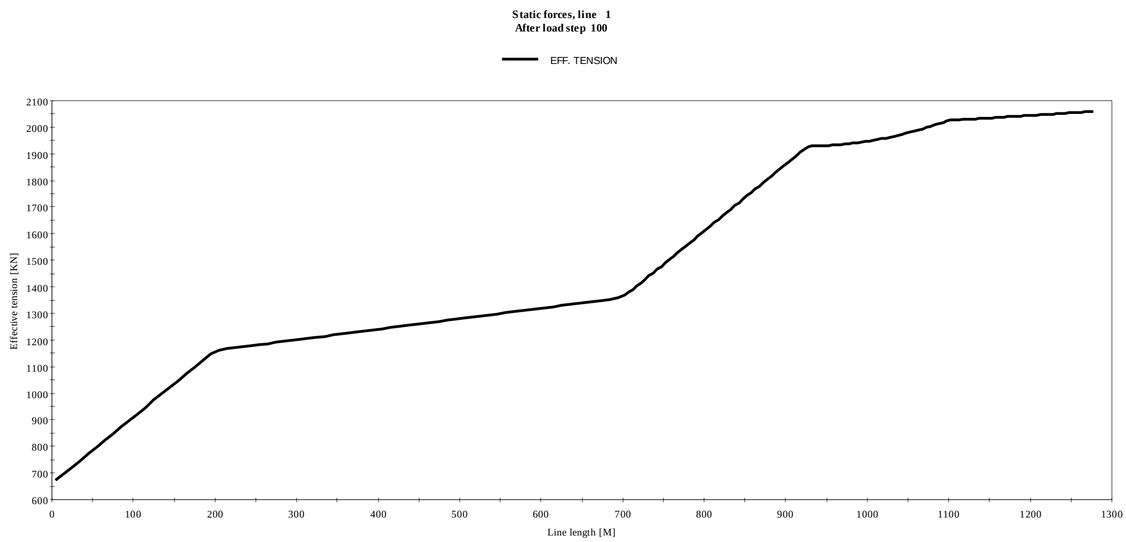

Displacement standard deviation, line 1
X
Y
Z
Standard deviation [M]
Line length [M]

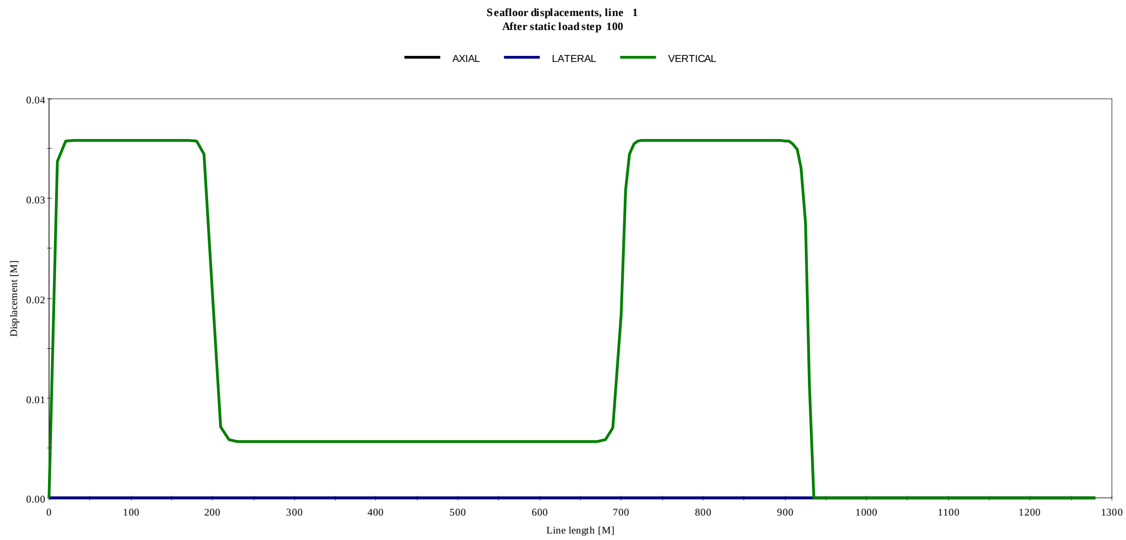

Force envelope curve, line 1
Total min and max values
F-MIN
F-MAX
[KN]
Line length [M]

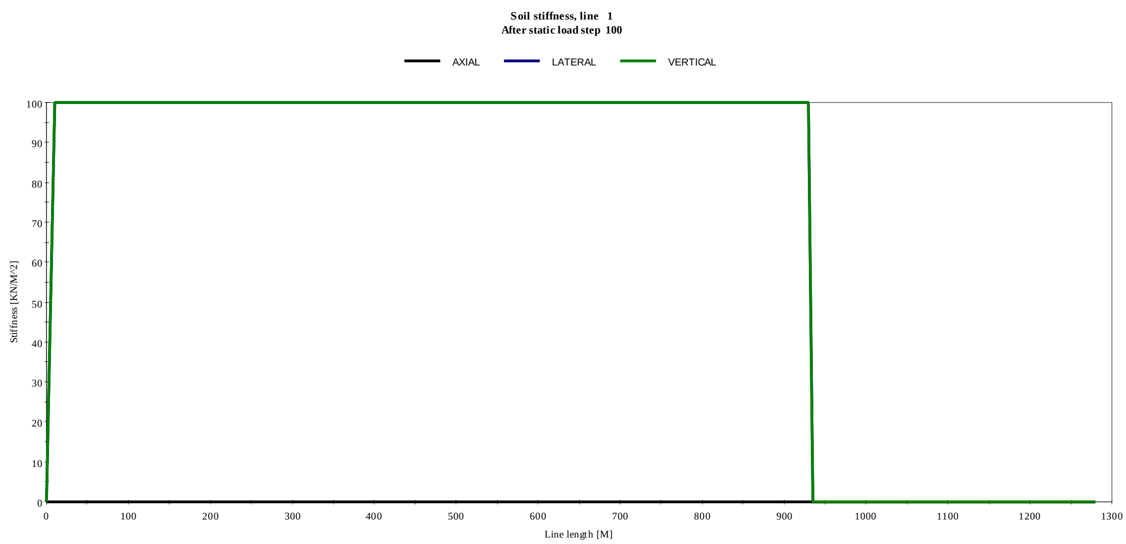

Force standard deviation, line 1
EFF. TENSION
Standard deviation [KN]
Line length [M]

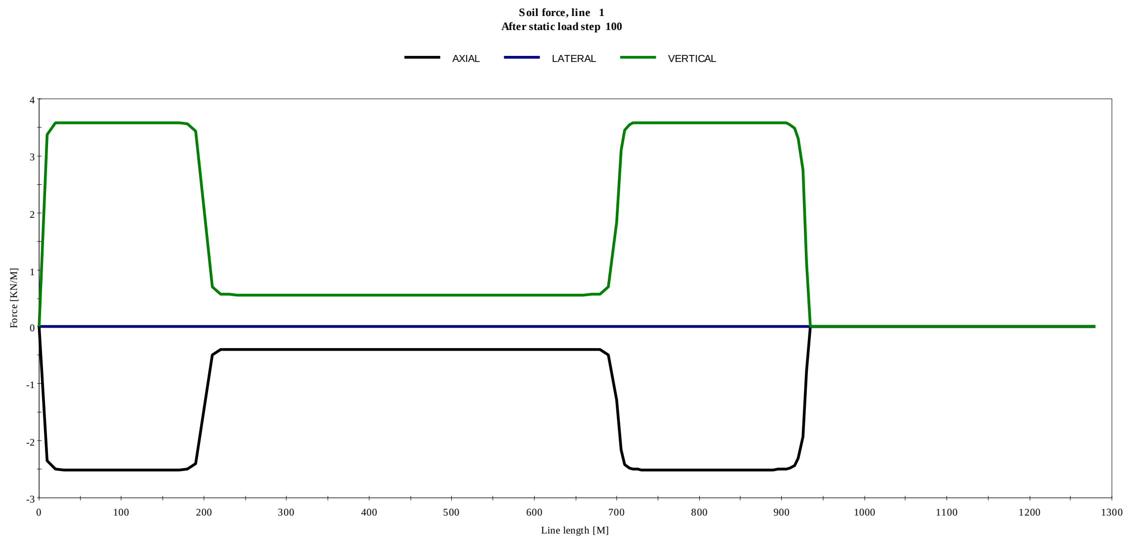
Case 1- water depth 100m
Ballasted – tension 15%MBL (2070KN) - H=15m, Period 11s

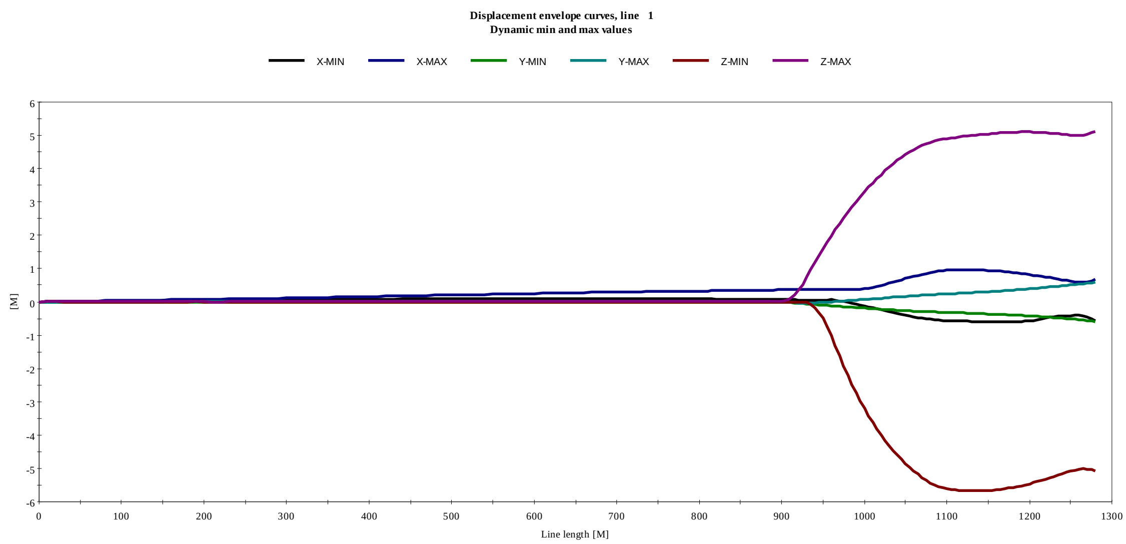


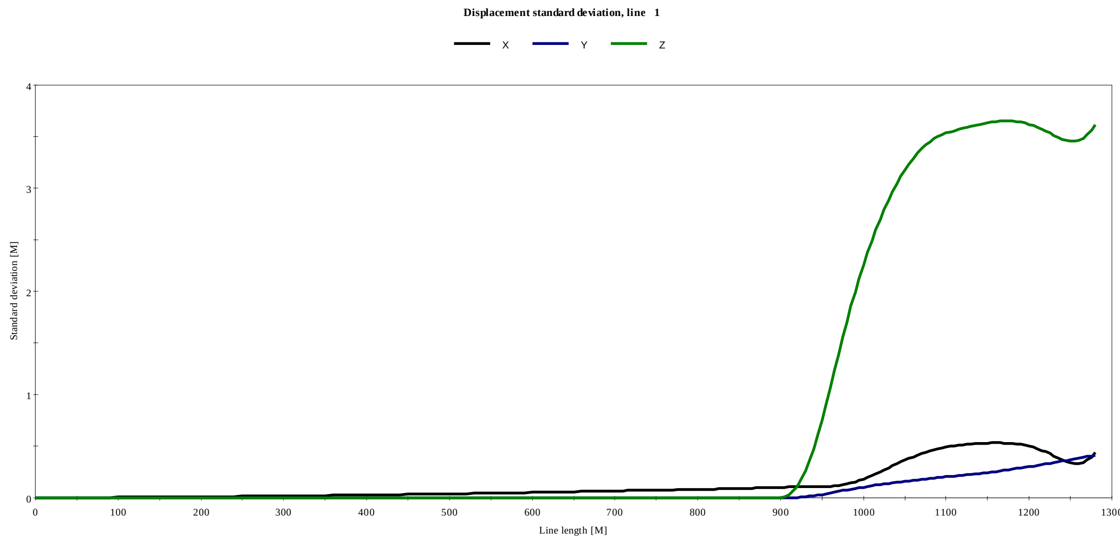


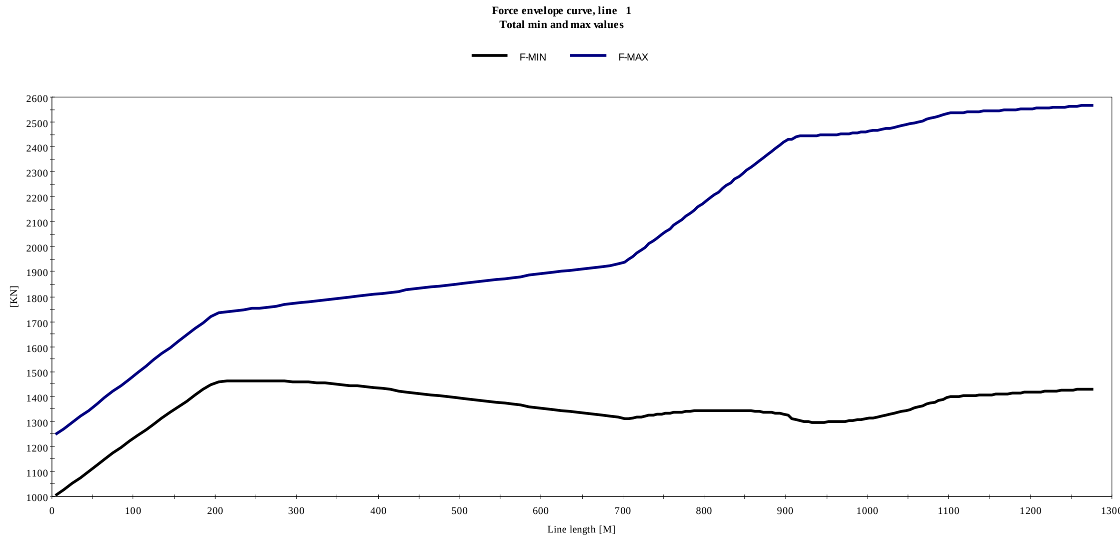

Seafloor displacements, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Displacement [M]
0.04
0.03
0.02
0.01
0.00
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
Line length [M]

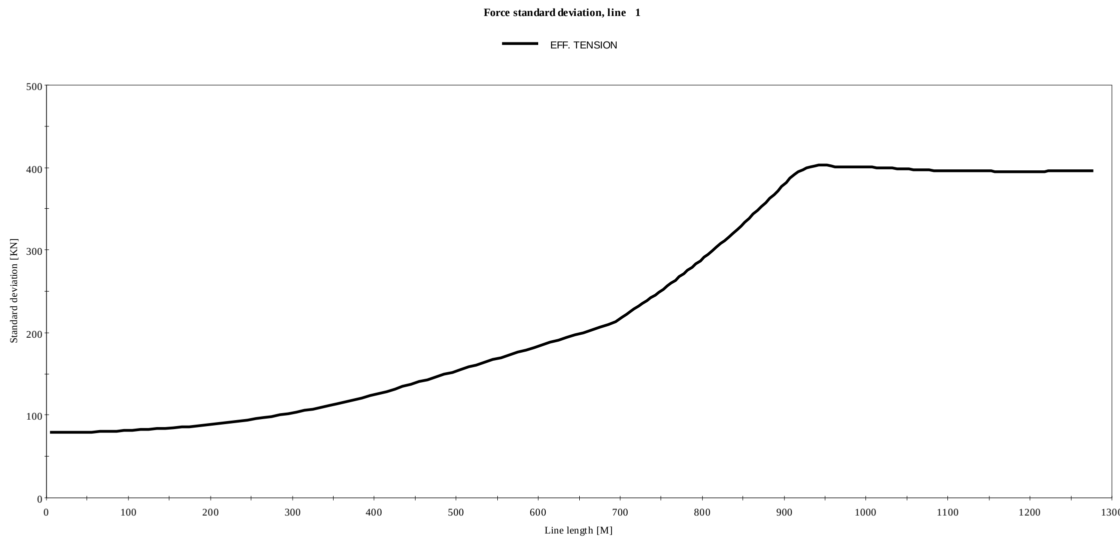

Soil stiffness, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Stiffness [KN/M^2]
100
90
80
70
60
50
40
30
20
10
0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
Line length [M]


Soil force, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Force [KN/M]
Line length [M]

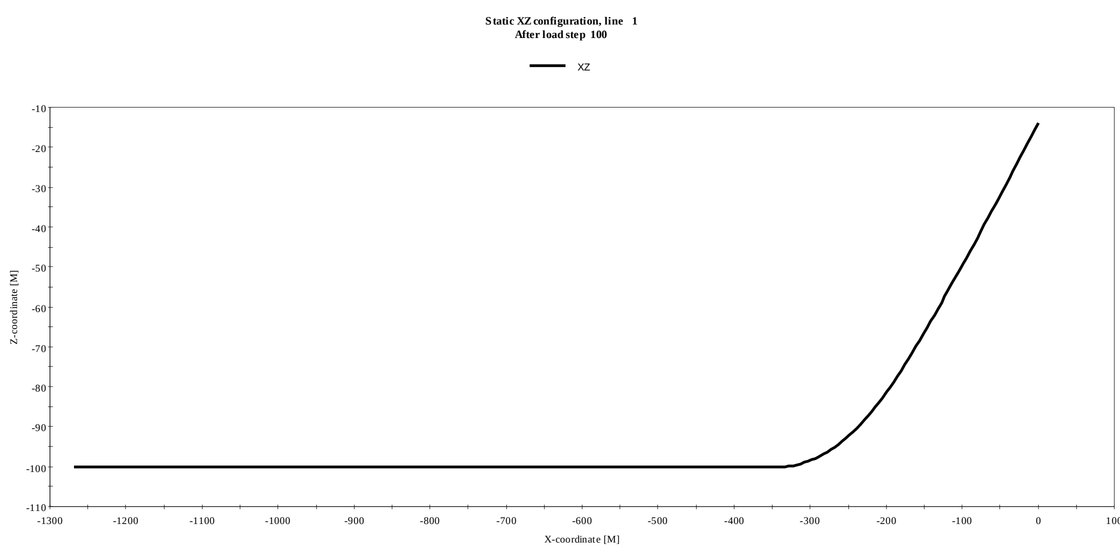

Displacement envelope curves, line 1
Dynamic min and max values
X-MIN
X-MAX
Y-MIN
Y-MAX
Z-MIN
Z-MAX
[M]
Line length [M]

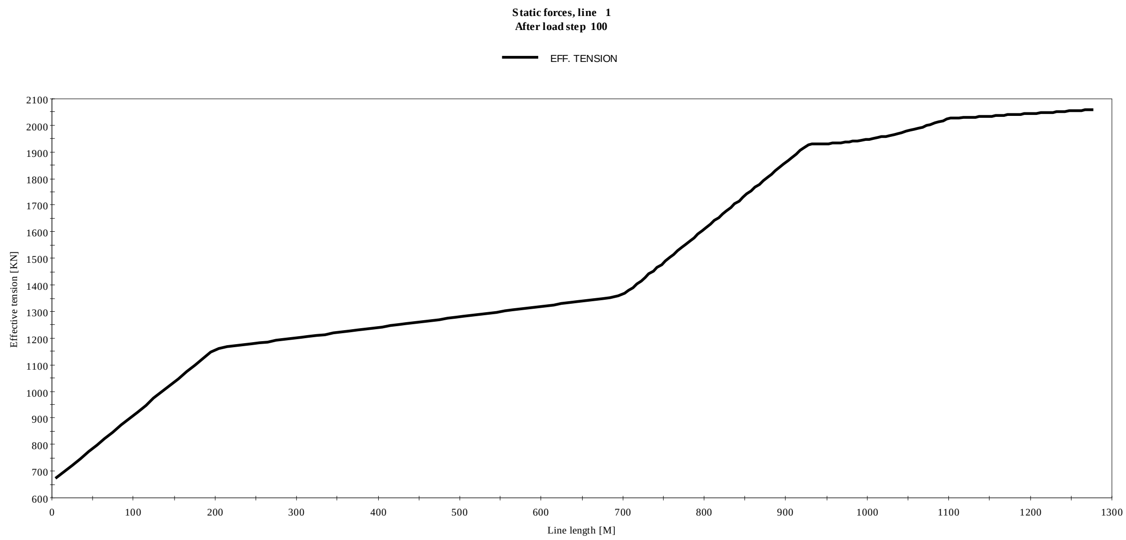

Displacement standard deviation, line 1
X
Y
Z
Standard deviation [M]
Line length [M]
0
1
2
3
4
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300

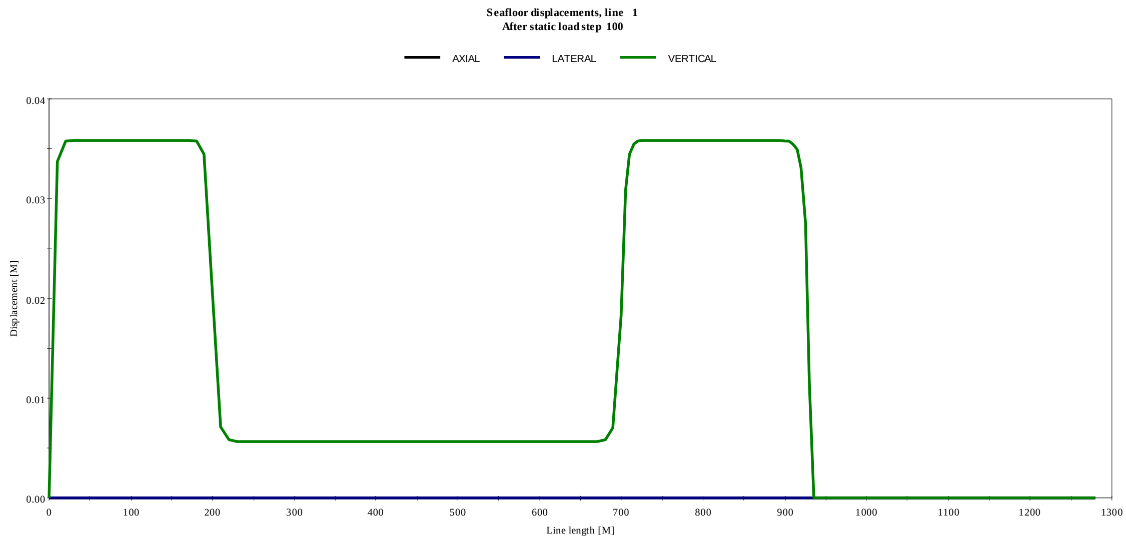

Force envelope curve, line 1
Total min and max values
F-MIN
F-MAX
[KN]
Line length [M]
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300

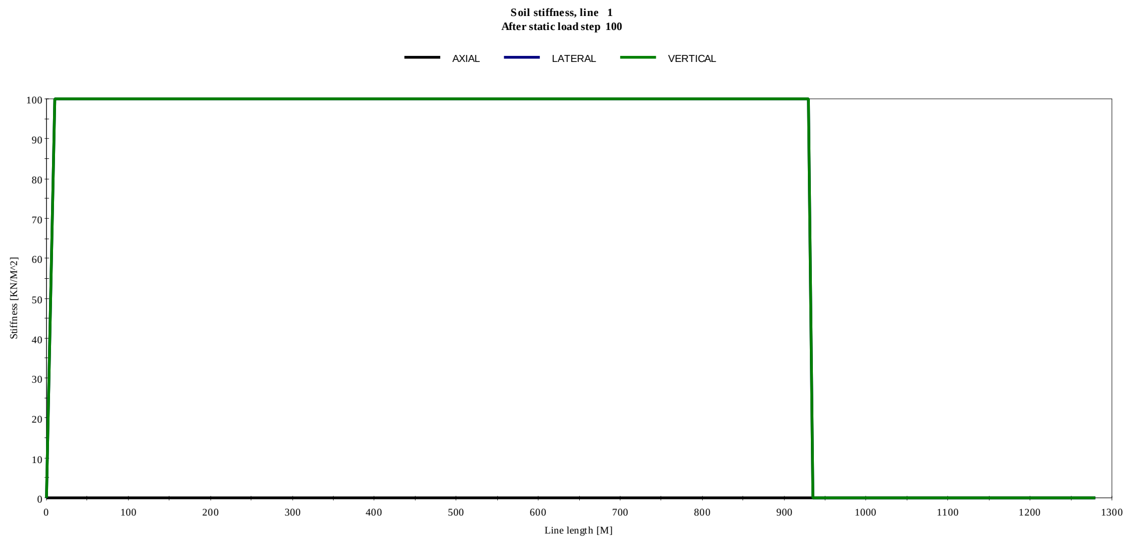


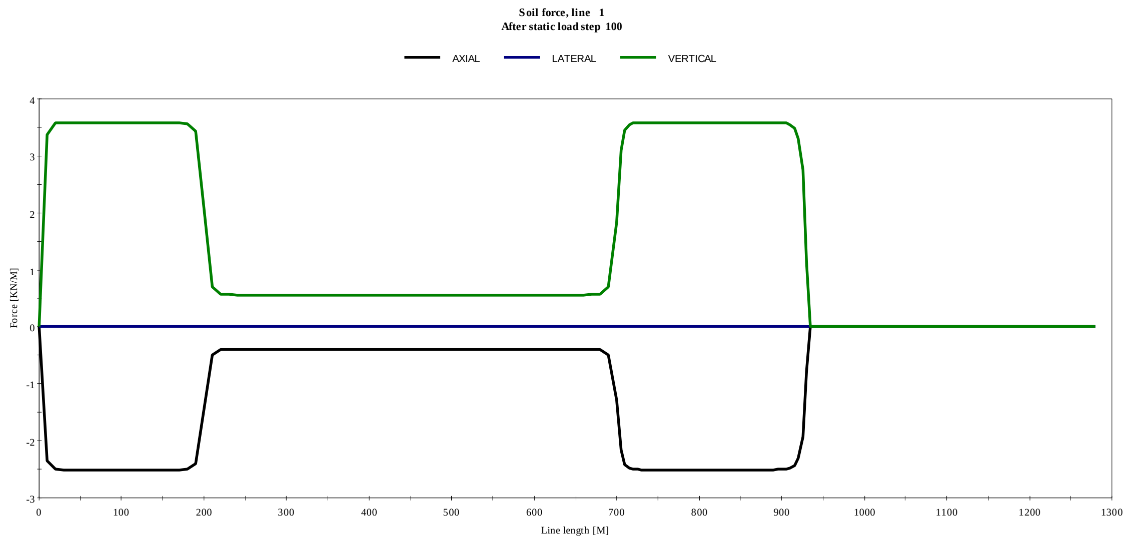
Case 1- water depth 100m
Ballasted – tension 15%MBL (2070KN) - H=15m, Period 12s

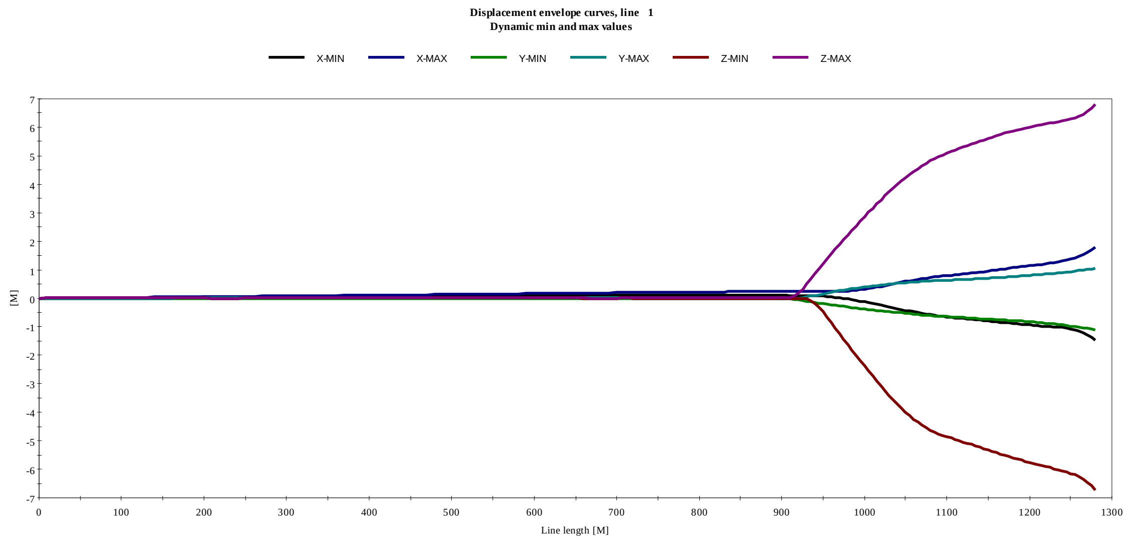


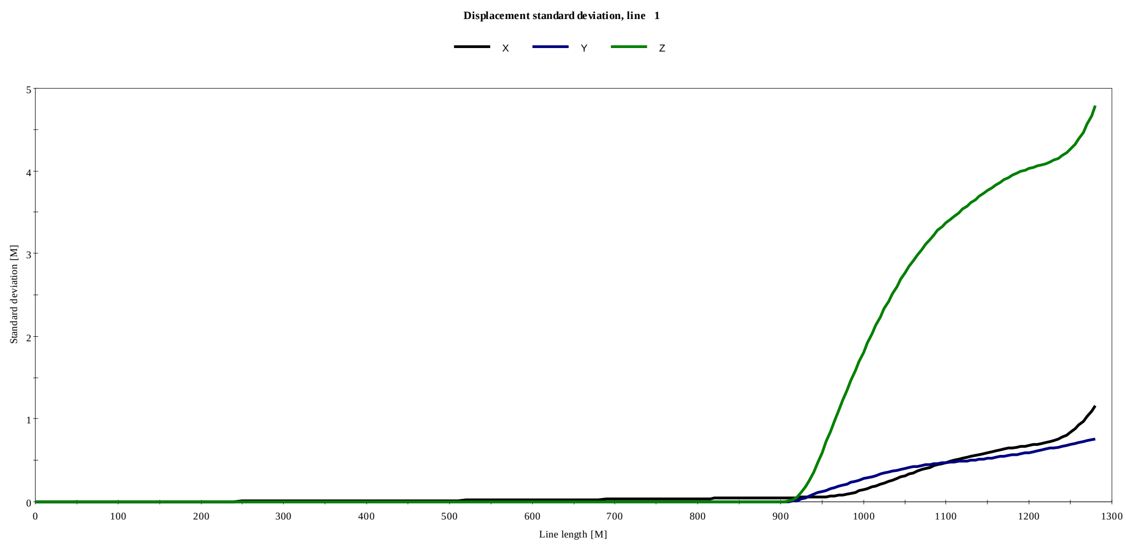

Static forces, line 1
After load step 100
EFF. TENSION
Effective tension [KN]
Line length [M]

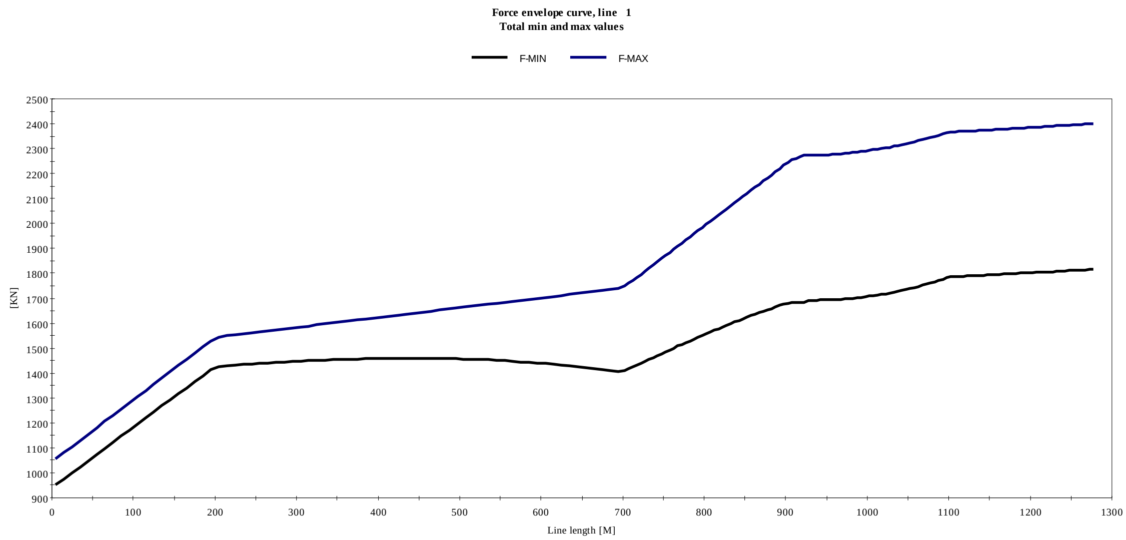

Seafloor displacements, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Displacement [M]
Line length [M]

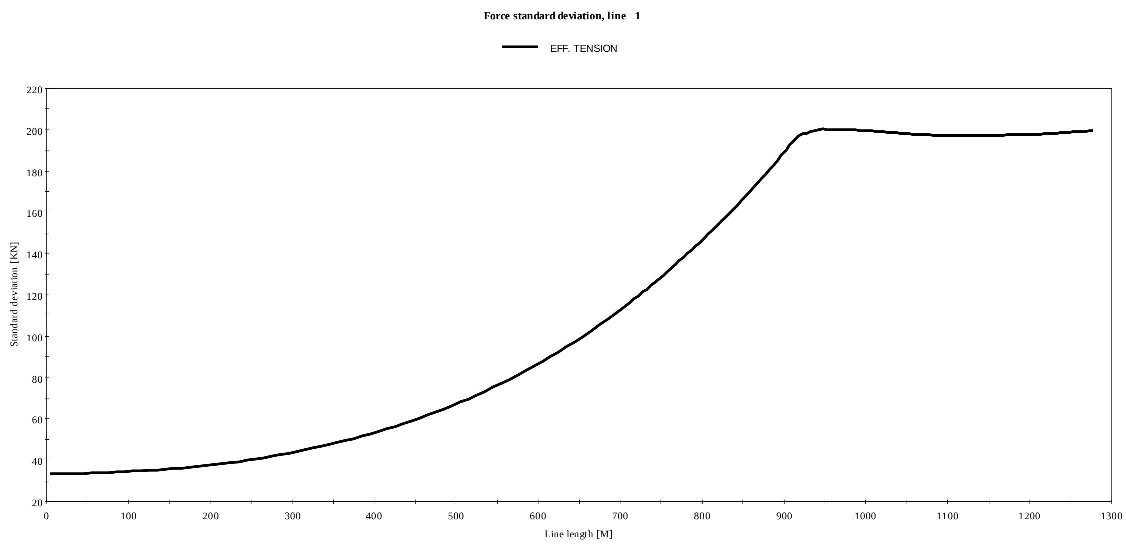

Soil stiffness, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Stiffness [KN/M^2]
Line length [M]


Soil force, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Force [KN/M]
Line length [M]

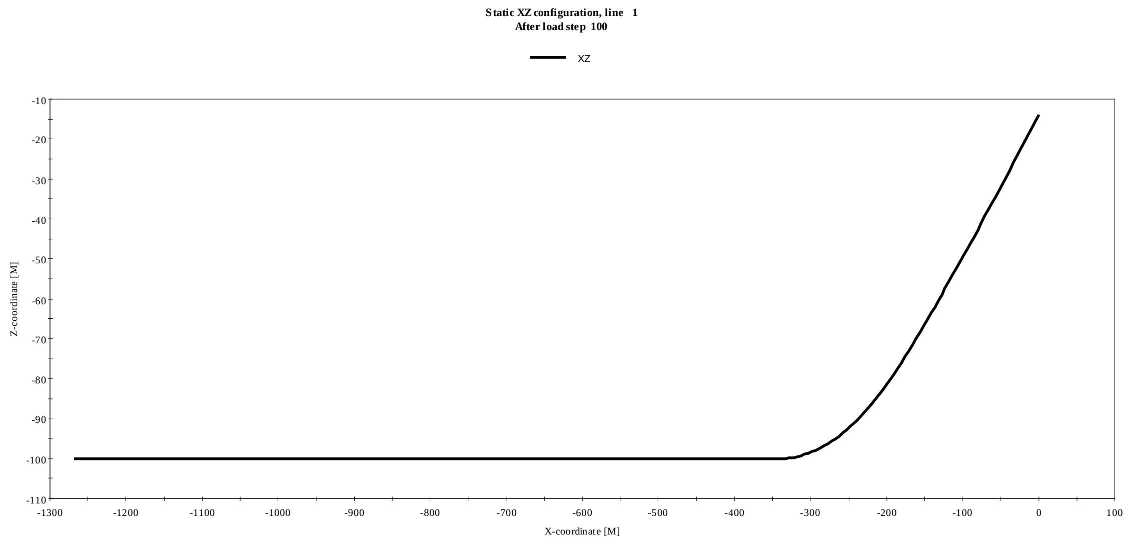

Displacement envelope curves, line 1
Dynamic min and max values
X-MIN
X-MAX
Y-MIN
Y-MAX
Z-MIN
Z-MAX
[M]
Line length [M]

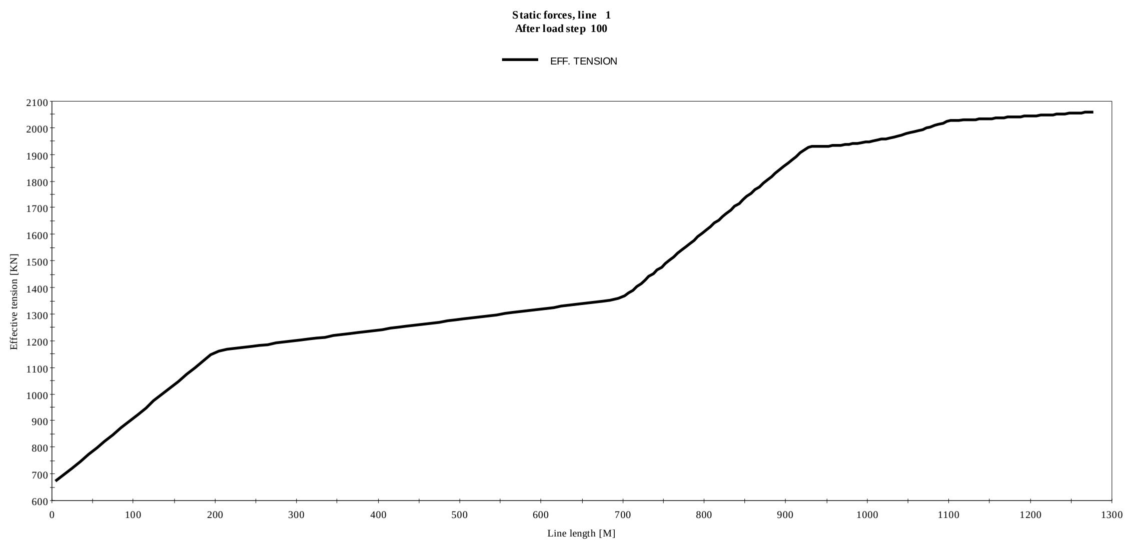

Displacement standard deviation, line 1
X
Y
Z
Standard deviation [M]
Line length [M]

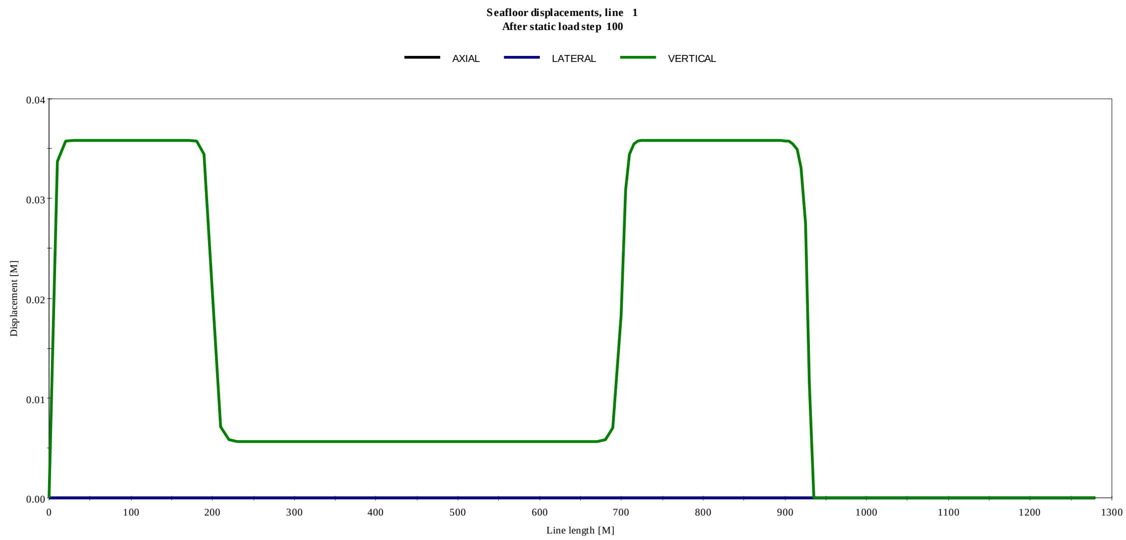

Force envelope curve, line 1
Total min and max values
F-MIN
F-MAX
[KN]
Line length [M]

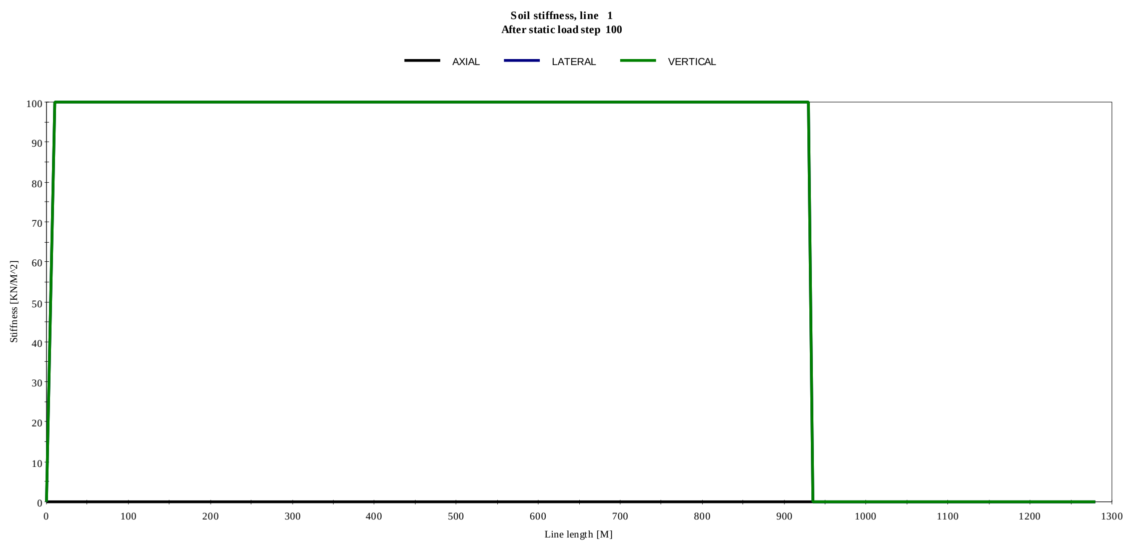

Force standard deviation, line 1
EFF. TENSION
Standard deviation [KN]
Line length [M]

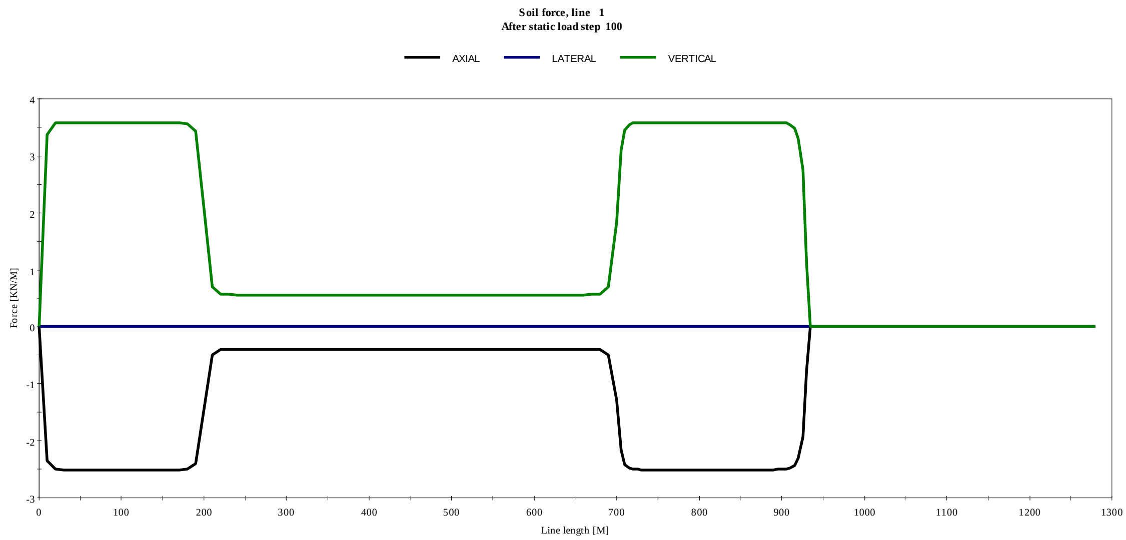
Case 1- water depth 100m
Ballasted – tension 15%MBL (2070KN) - H=15m, Period 13s

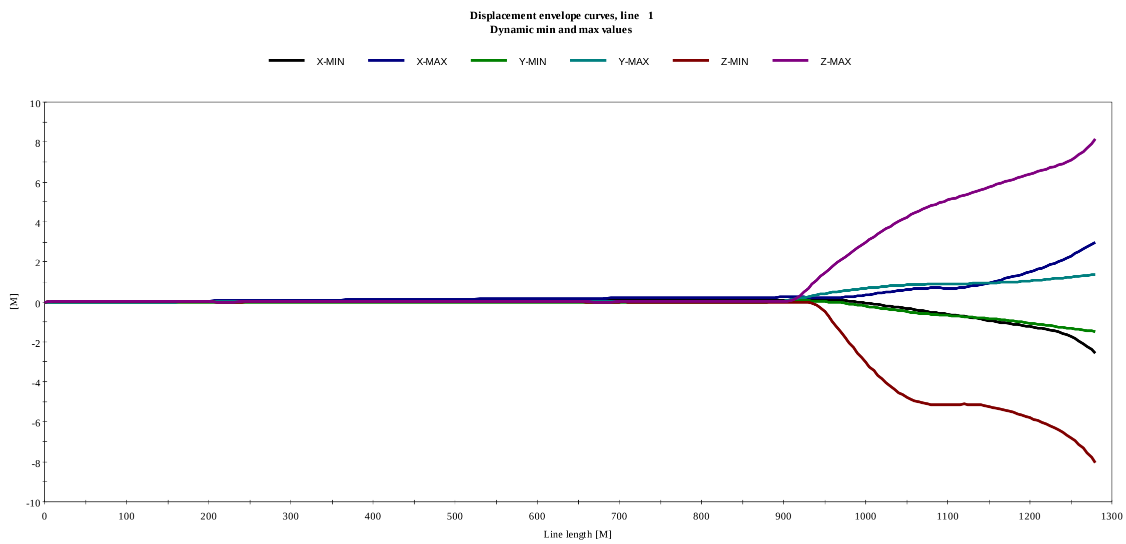


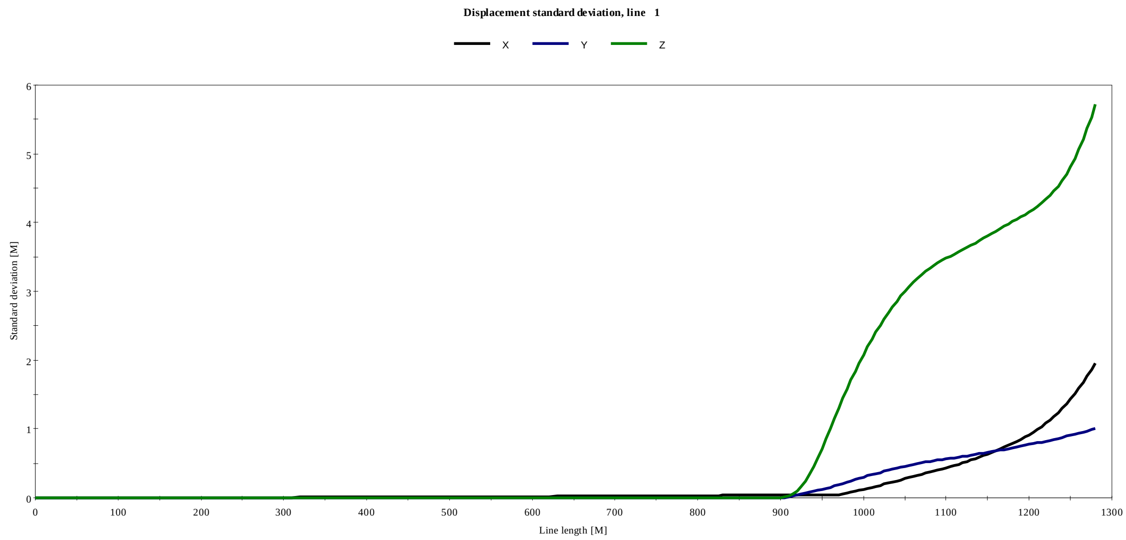


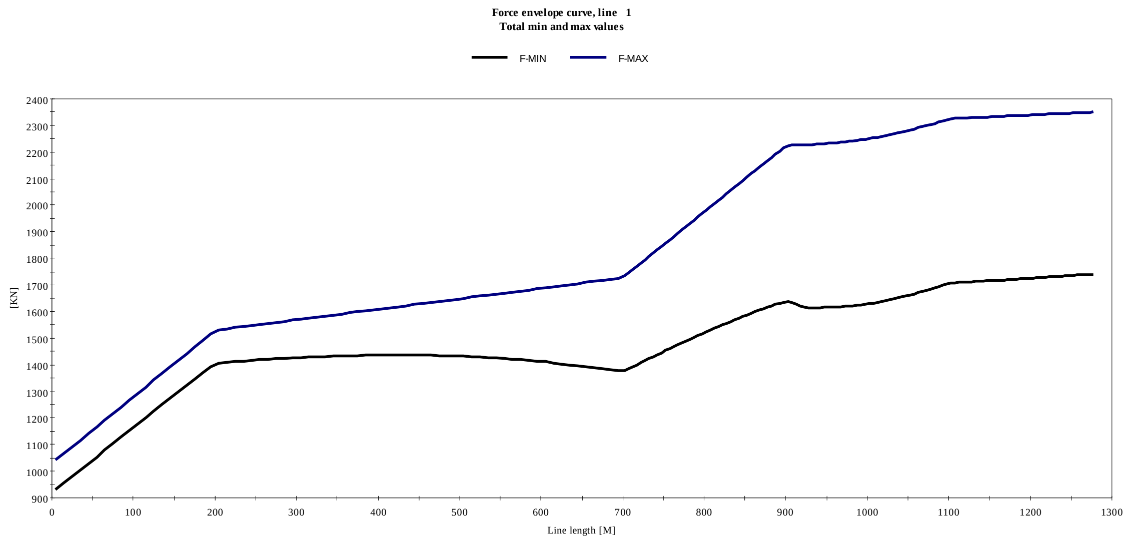

Seafloor displacements, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Displacement [M]
Line length [M]

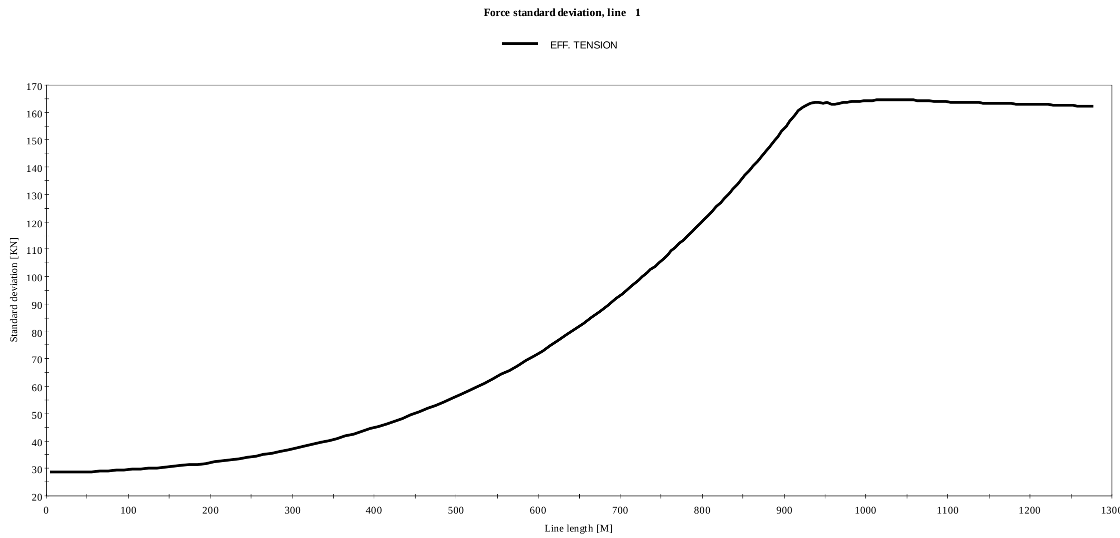

Soil stiffness, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Stiffness [KN/M^2]
Line length [M]


Soil force, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Force [KN/M]
Line length [M]

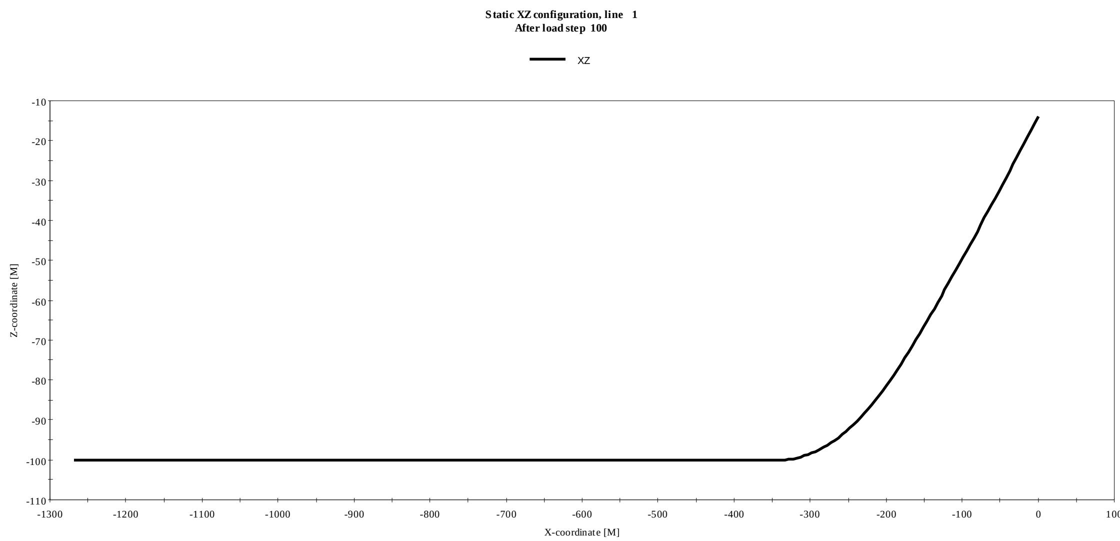

Displacement envelope curves, line 1
Dynamic min and max values
X-MIN
X-MAX
Y-MIN
Y-MAX
Z-MIN
Z-MAX
[M]
Line length [M]

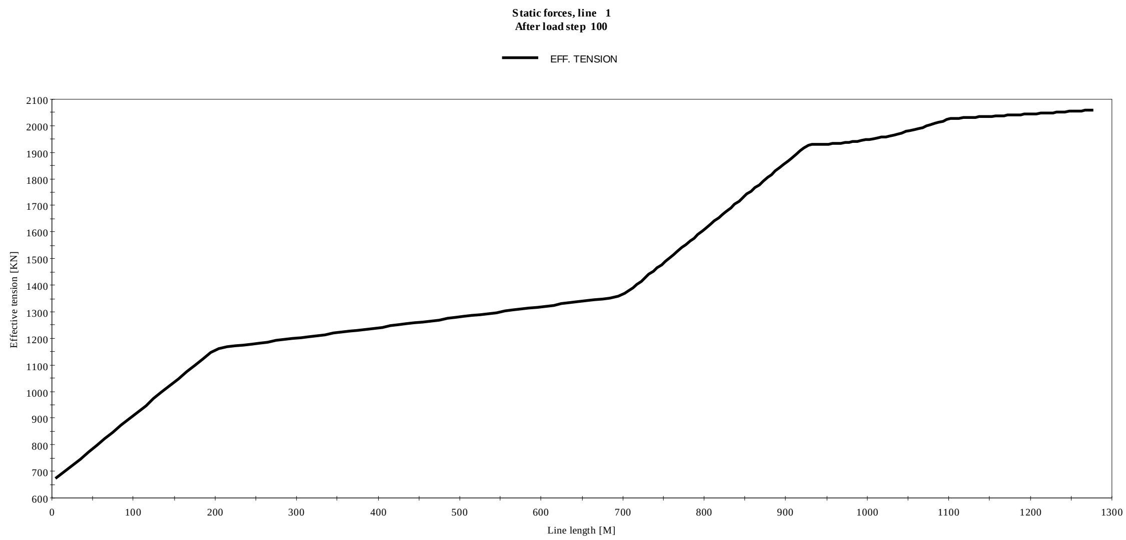

Displacement standard deviation, line 1
X
Y
Z
Standard deviation [M]
Line length [M]

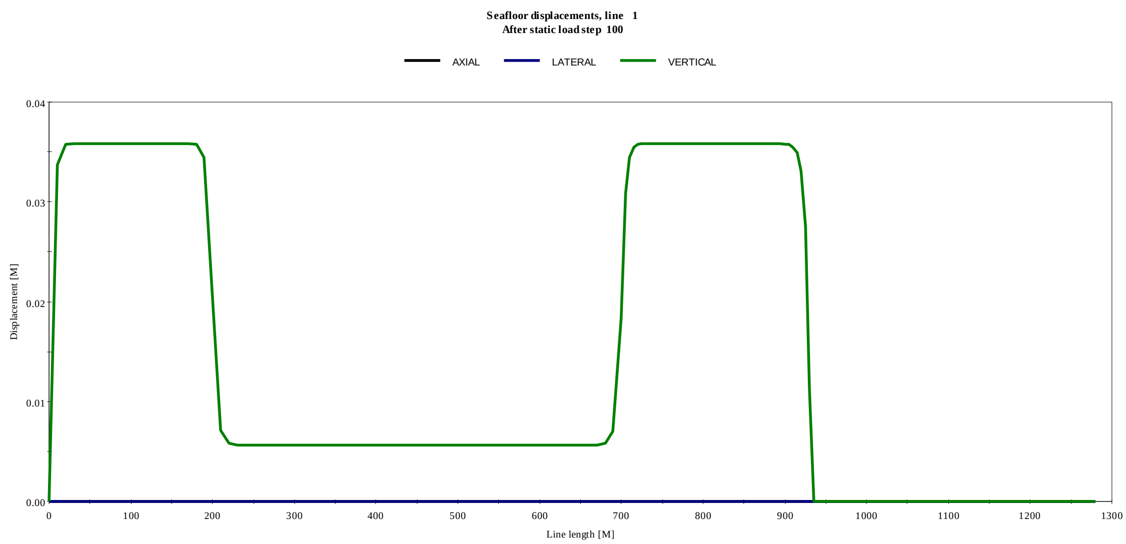

Force envelope curve, line 1
Total min and max values
F-MIN
F-MAX
[KN]
Line length [M]

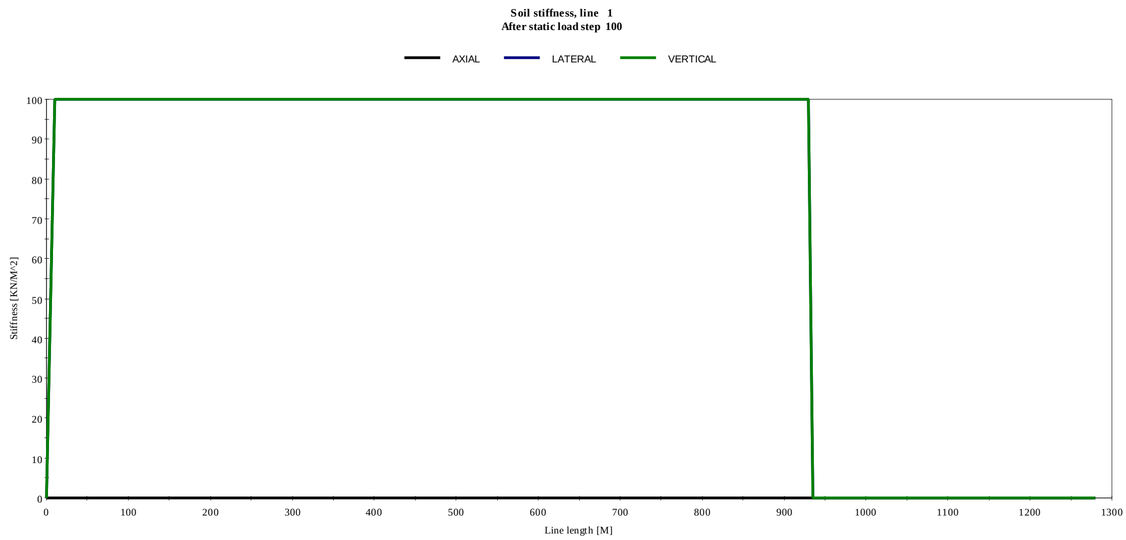


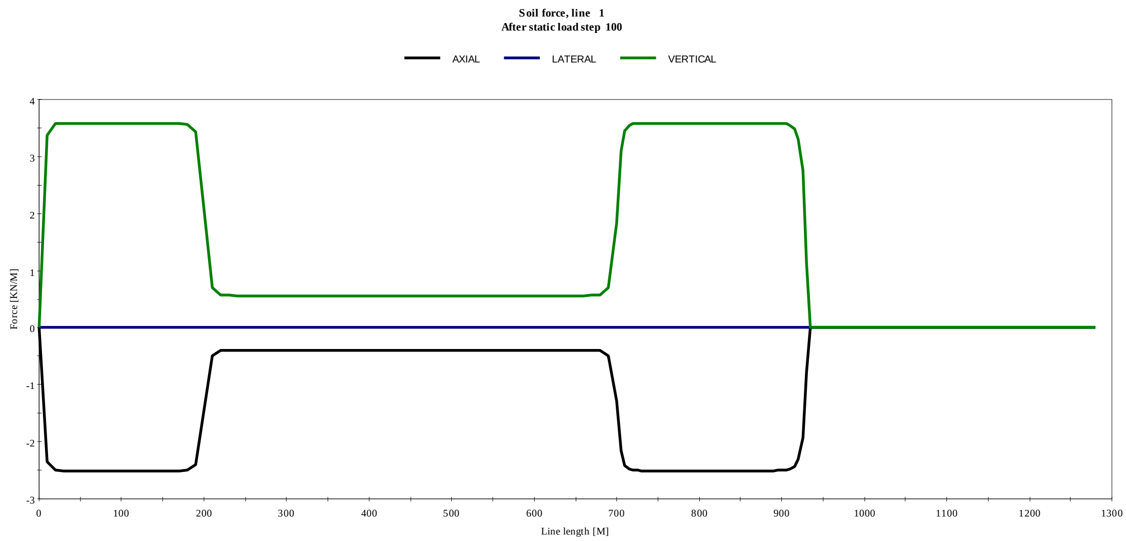
Case 1- water depth 100m
Ballasted – tension 15%MBL (2070KN) - H=15m, Period 14s

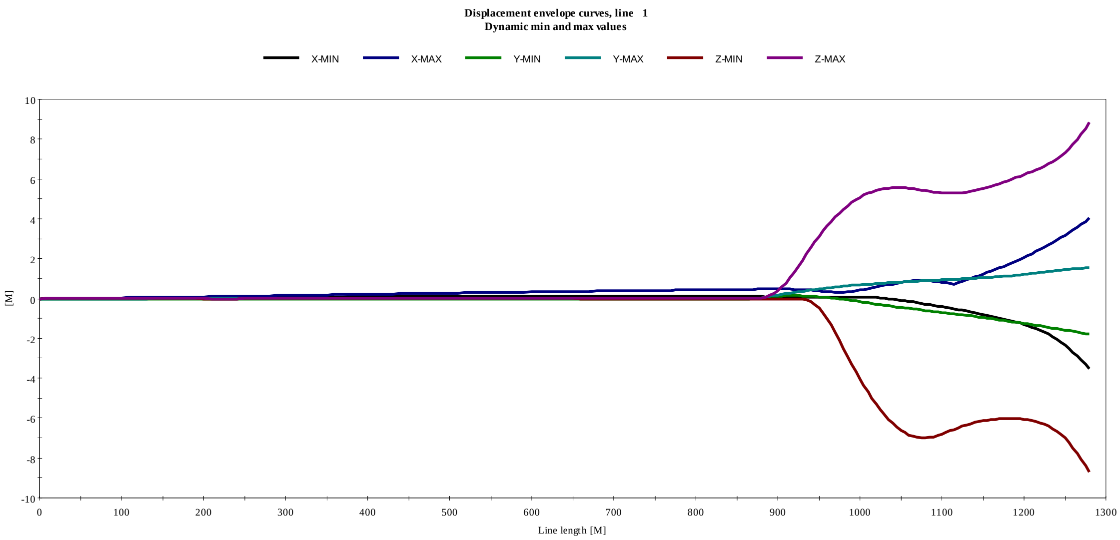


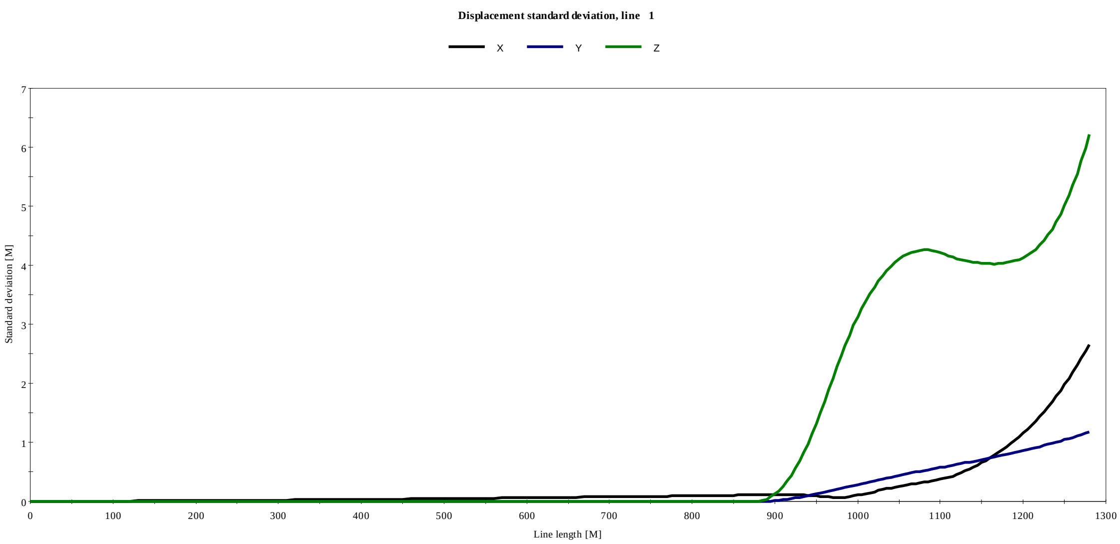

Static forces, line 1
After load step 100
EFF. TENSION
Effective tension [KN]
Line length [M]

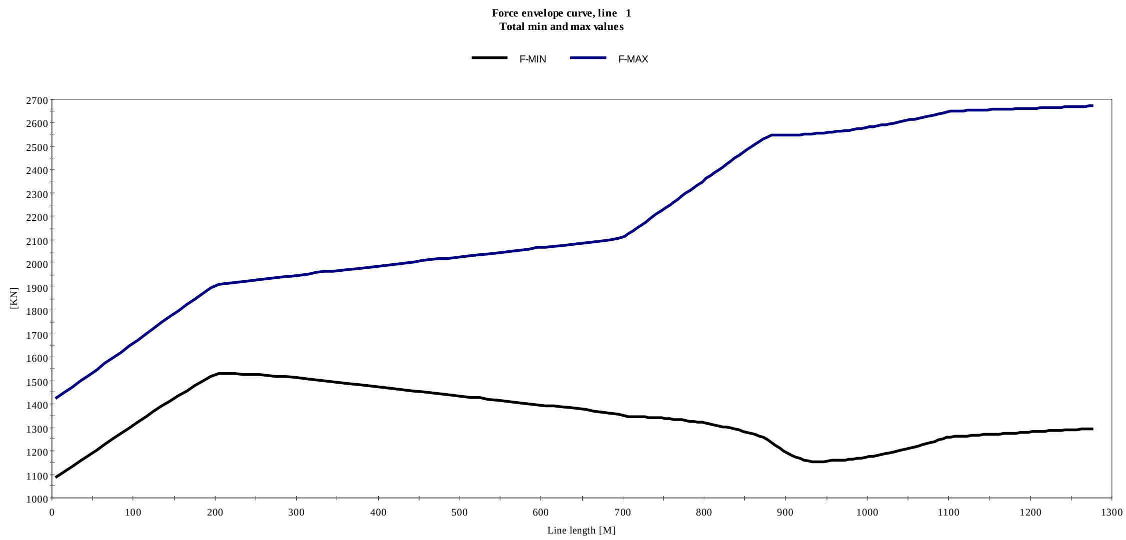

Seafloor displacements, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Displacement [M]
Line length [M]

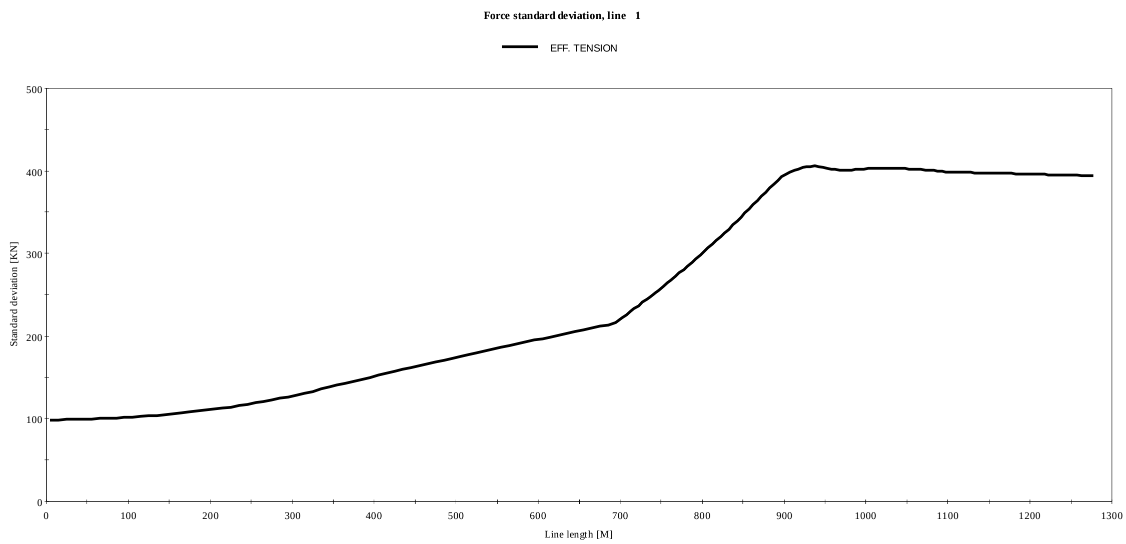

Soil stiffness, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Stiffness [KN/M^2]
Line length [M]


Soil force, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Force [KN/M]
Line length [M]

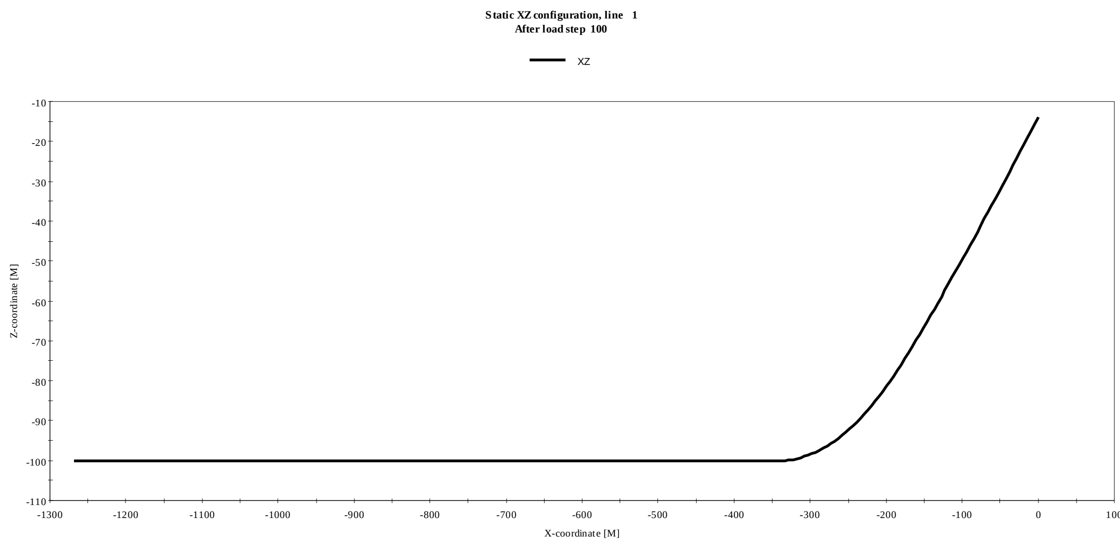

Displacement envelope curves, line 1
Dynamic min and max values
X-MIN
X-MAX
Y-MIN
Y-MAX
Z-MIN
Z-MAX
[M]
Line length [M]

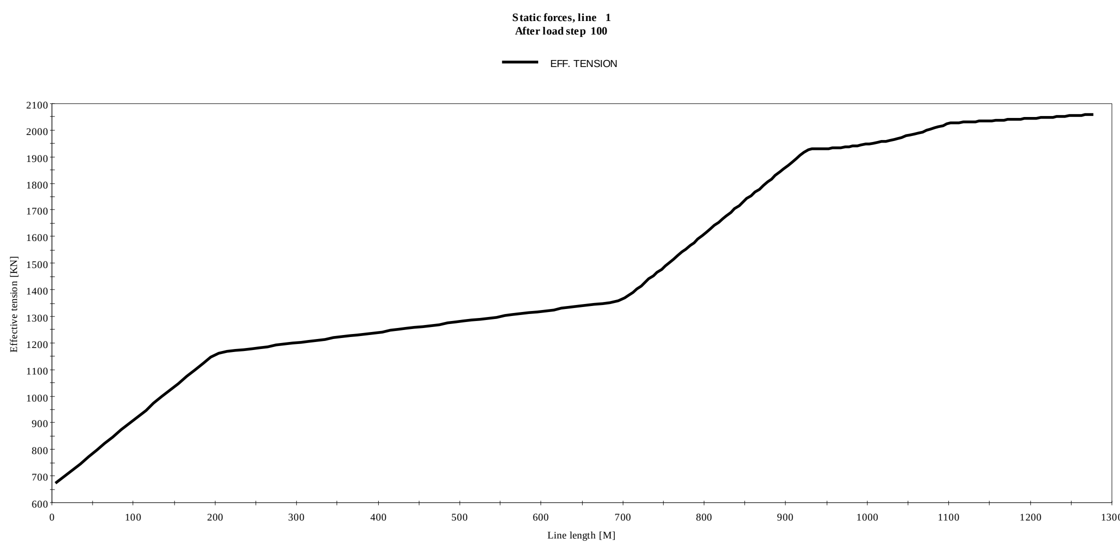

Displacement standard deviation, line 1
X
Y
Z
Standard deviation [M]
Line length [M]

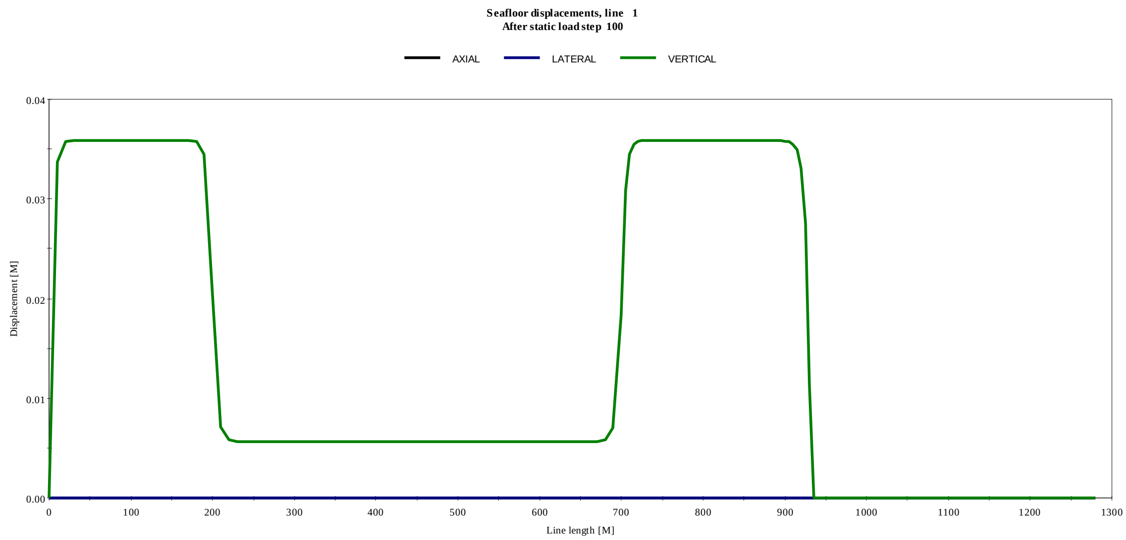

Force envelope curve, line 1
Total min and max values
F-MIN
F-MAX
[KN]
Line length [M]

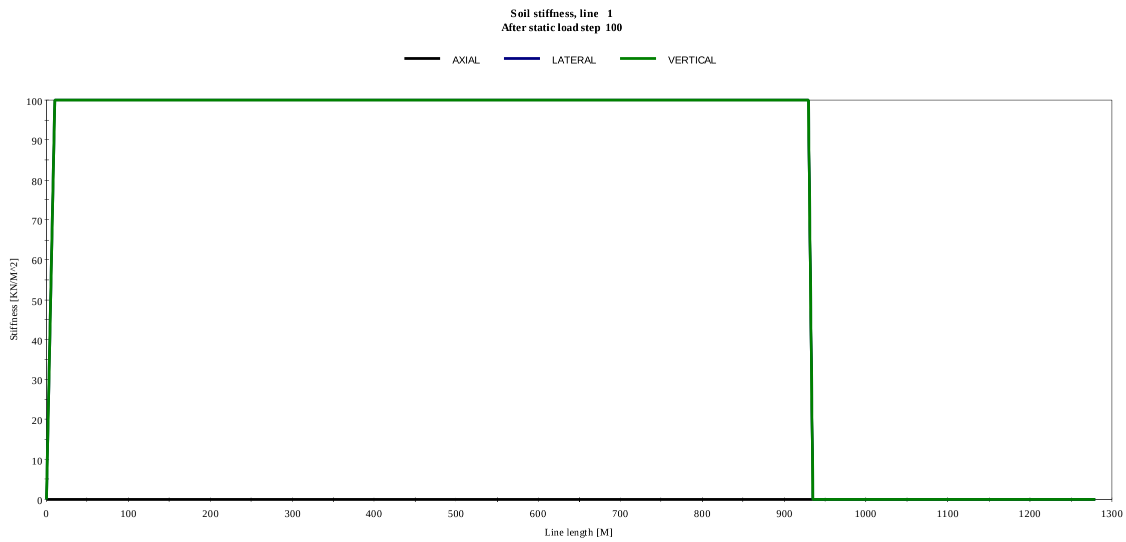

Force standard deviation, line 1
EFF. TENSION
Standard deviation [KN]
Line length [M]

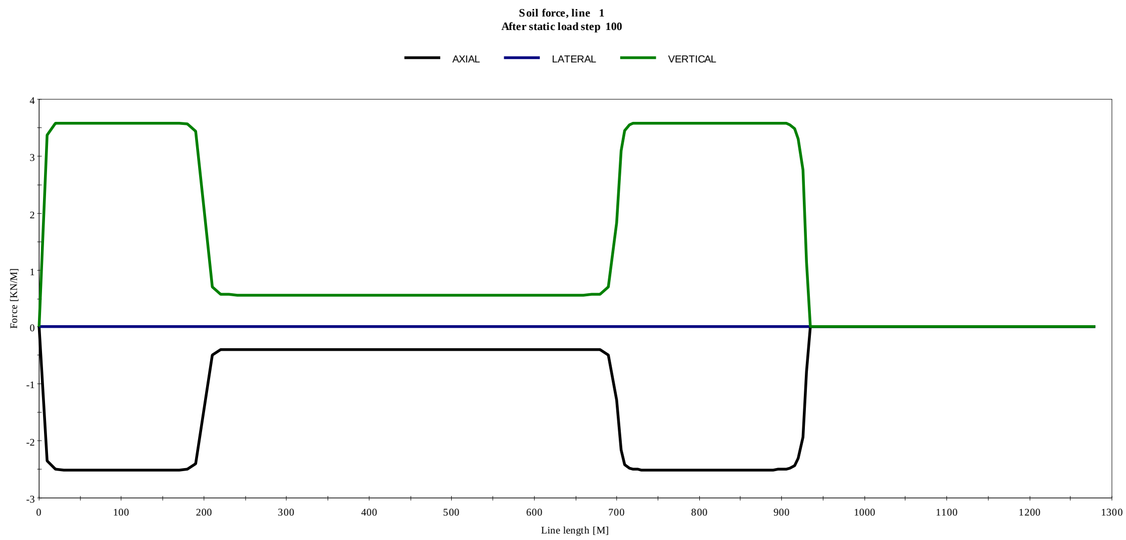
Case 1- water depth 100m
Ballasted – tension 15%MBL (2070KN) - H=15m, Period 15s

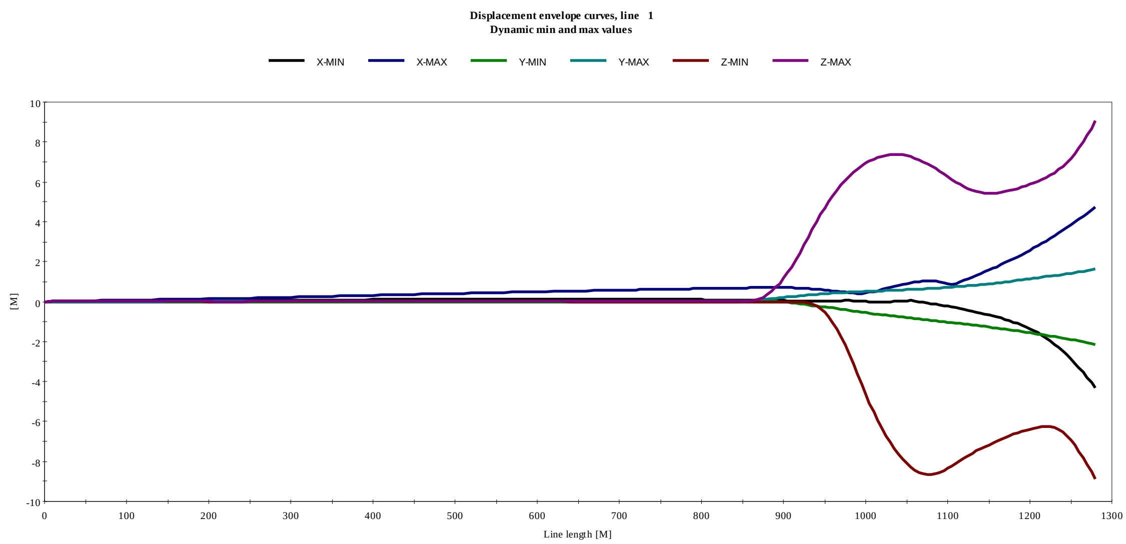


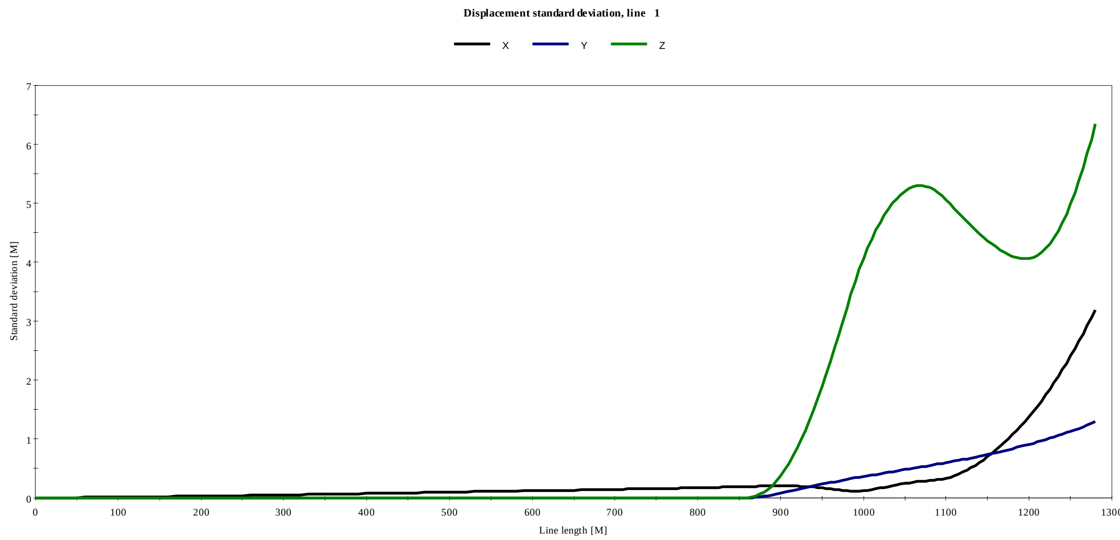


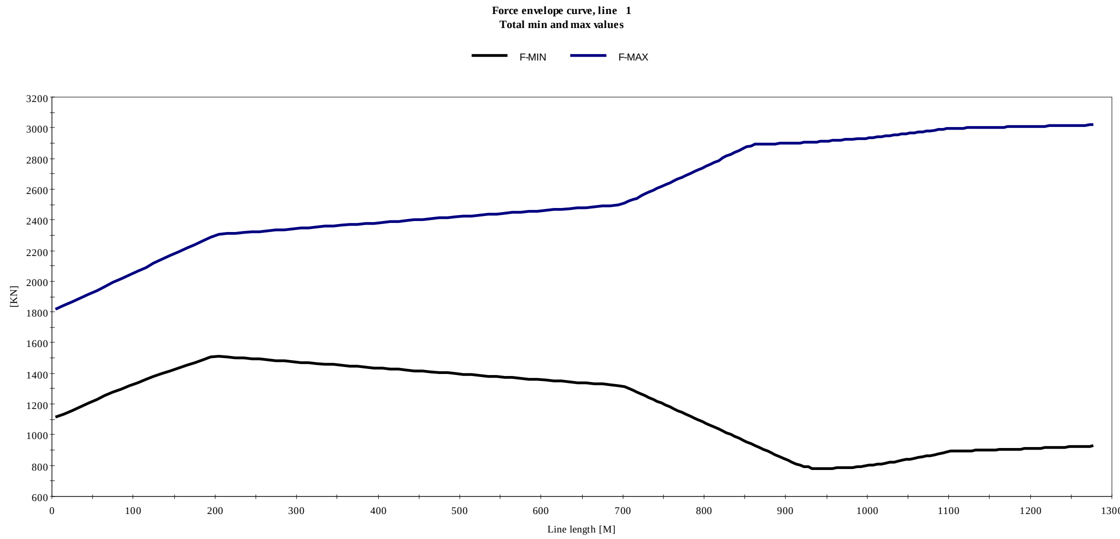

Seafloor displacements, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Displacement [M]
Line length [M]

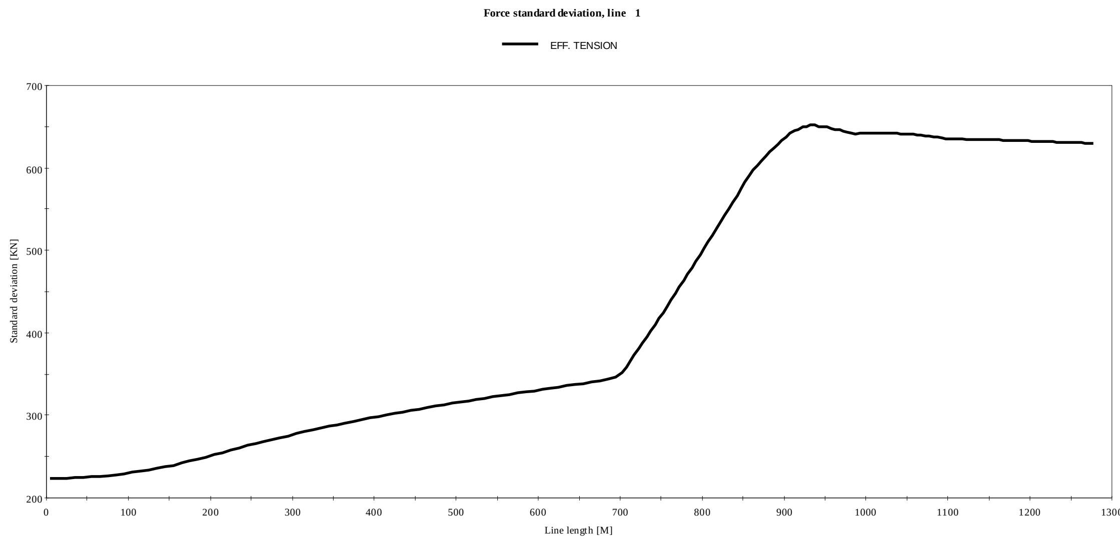

Soil stiffness, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Stiffness [KN/M^2]
Line length [M]


Soil force, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Force [KN/M]
Line length [M]

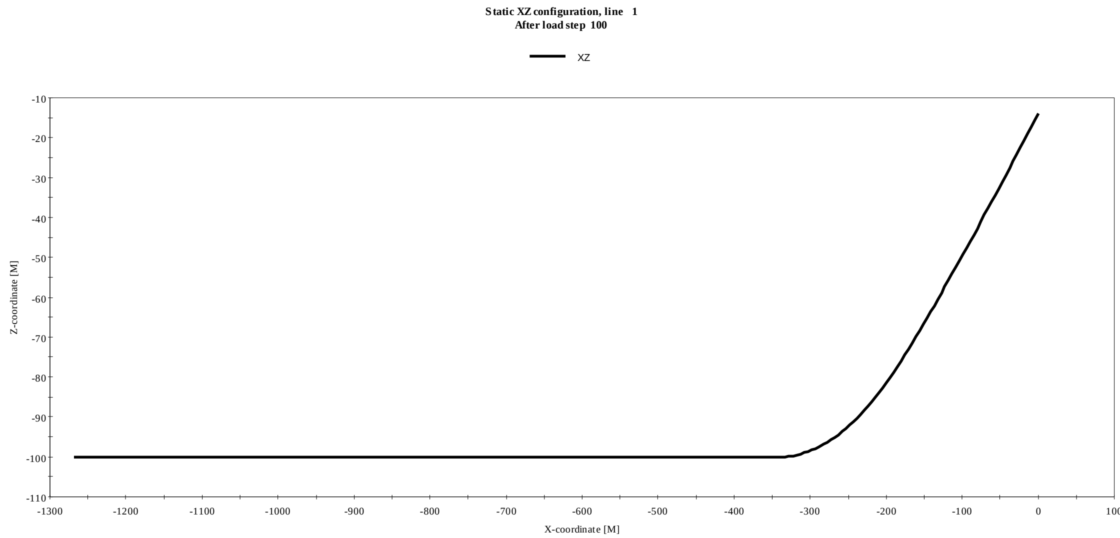

Displacement envelope curves, line 1
Dynamic min and max values
X-MIN
X-MAX
Y-MIN
Y-MAX
Z-MIN
Z-MAX
[M]
Line length [M]

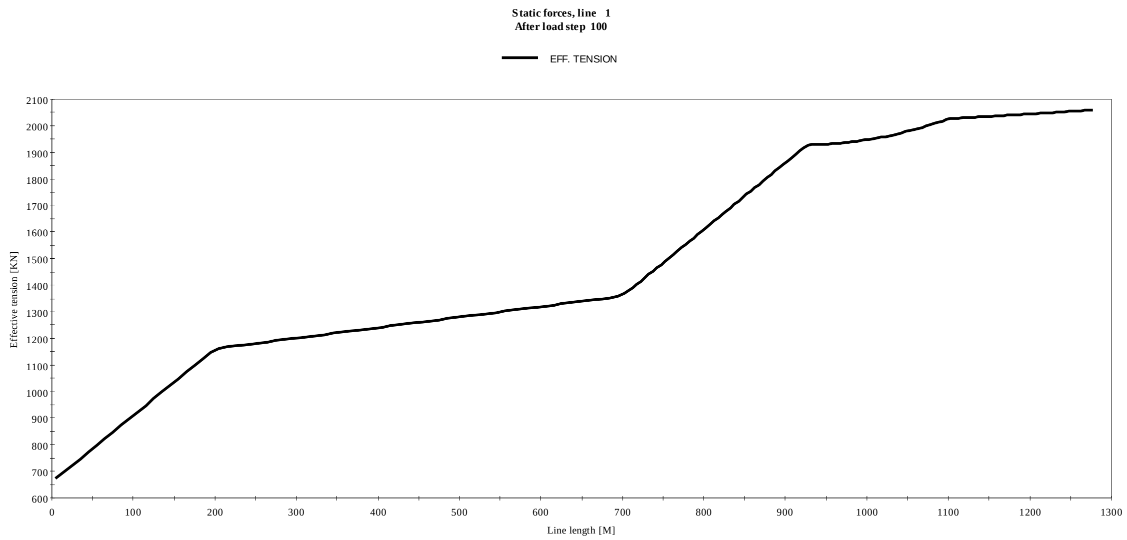

Displacement standard deviation, line 1
X
Y
Z
Standard deviation [M]
Line length [M]

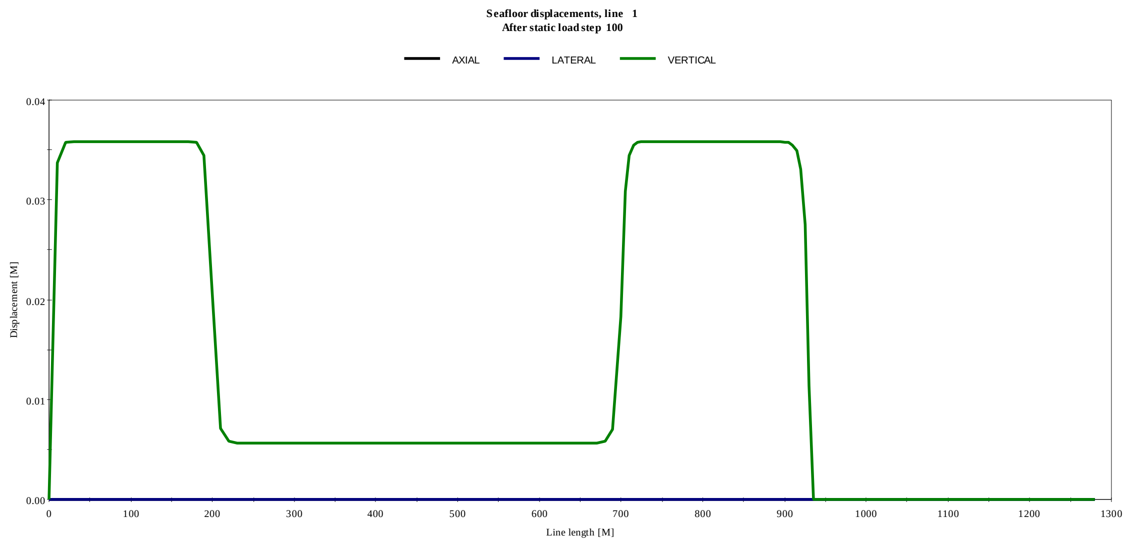

Force envelope curve, line 1
Total min and max values
F-MIN
F-MAX
[KN]
Line length [M]

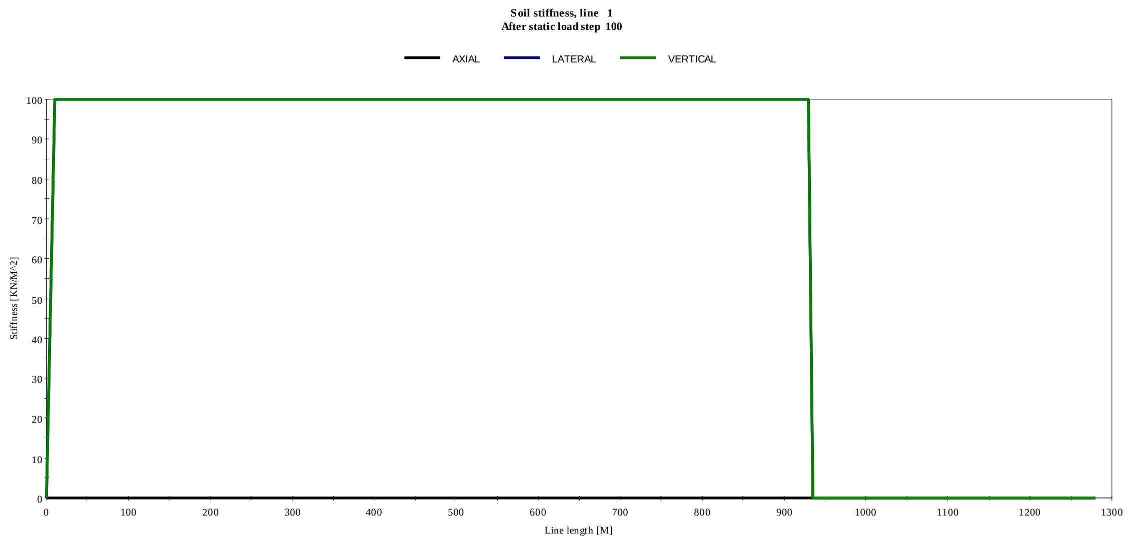


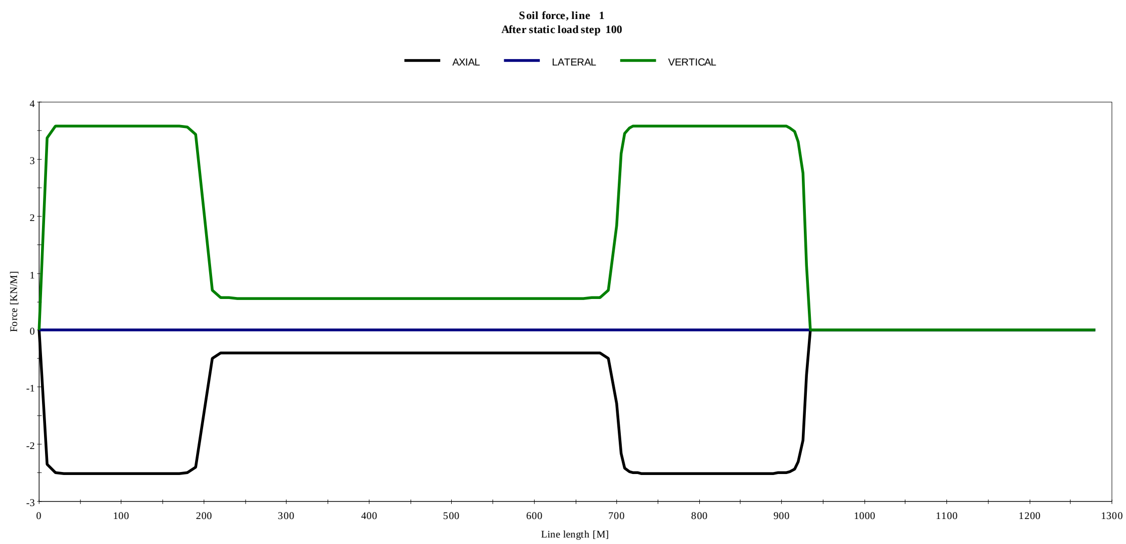
Case 1- water depth 100m
Ballasted – tension 15%MBL (2070KN) - H=30m, Period 13s

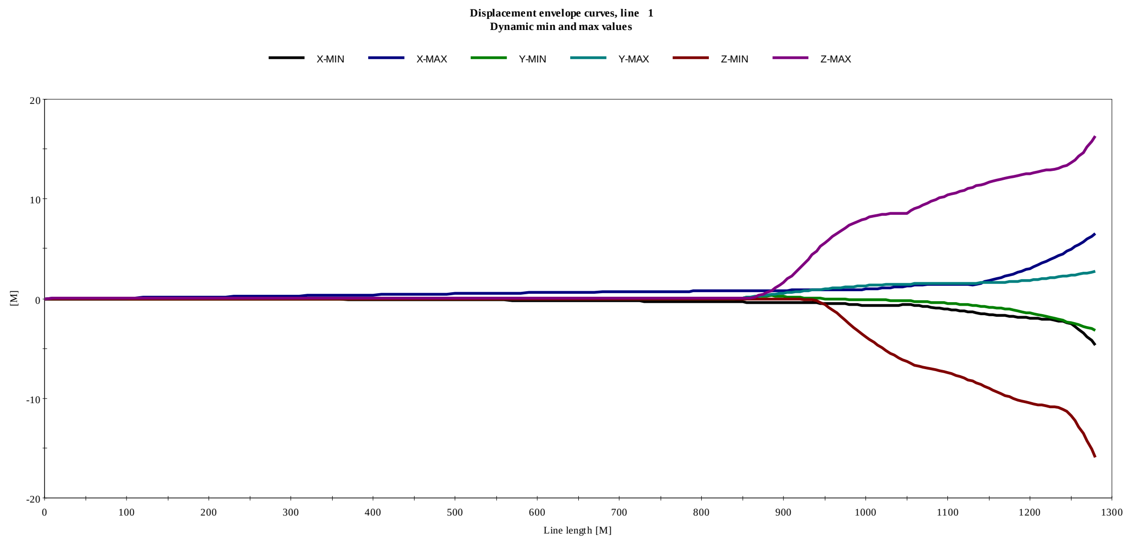


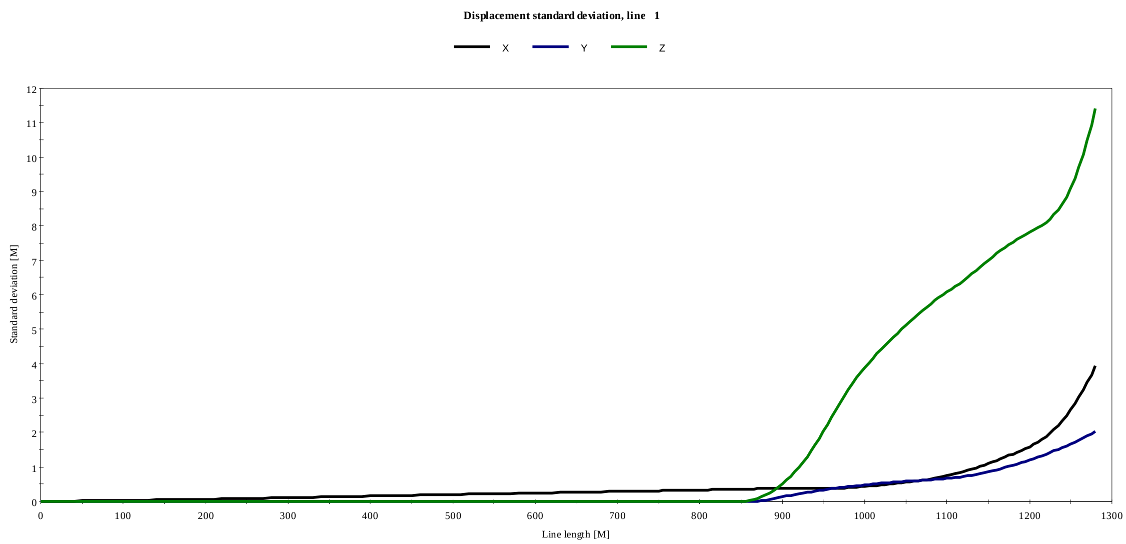

Static forces, line 1
After load step 100
EFF. TENSION
Effective tension [KN]
Line length [M]

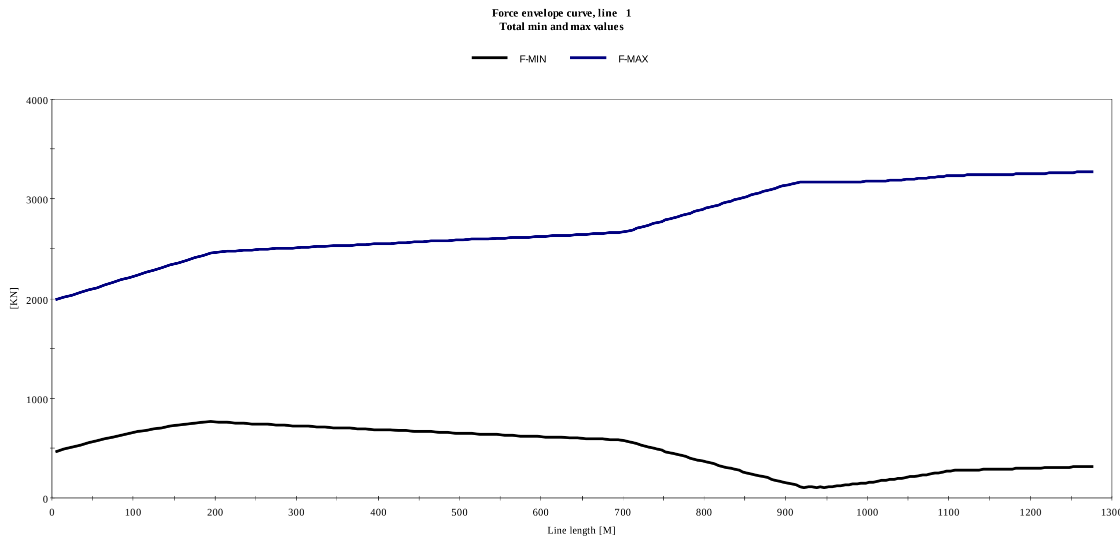

Seafloor displacements, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Displacement [M]
Line length [M]

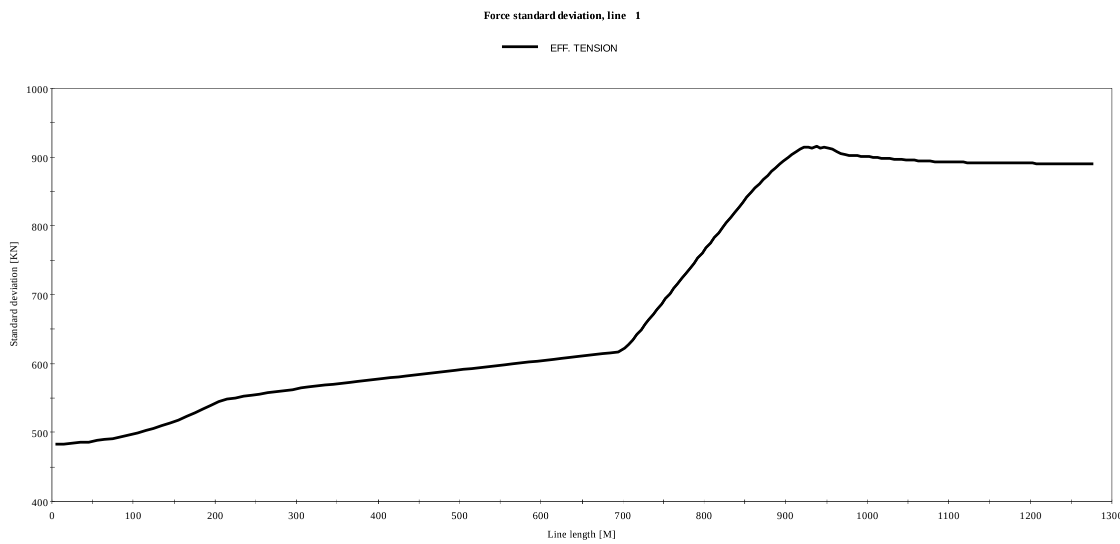

Soil stiffness, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Stiffness [KN/M^2]
Line length [M]


Soil force, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Force [KN/M]
Line length [M]

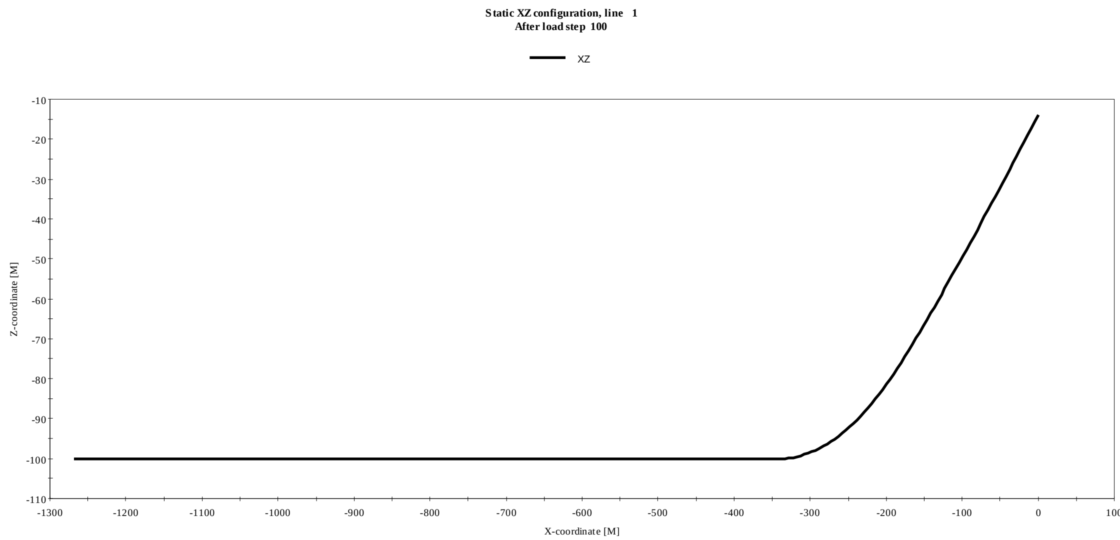

Displacement envelope curves, line 1
Dynamic min and max values
X-MIN
X-MAX
Y-MIN
Y-MAX
Z-MIN
Z-MAX
[M]
Line length [M]

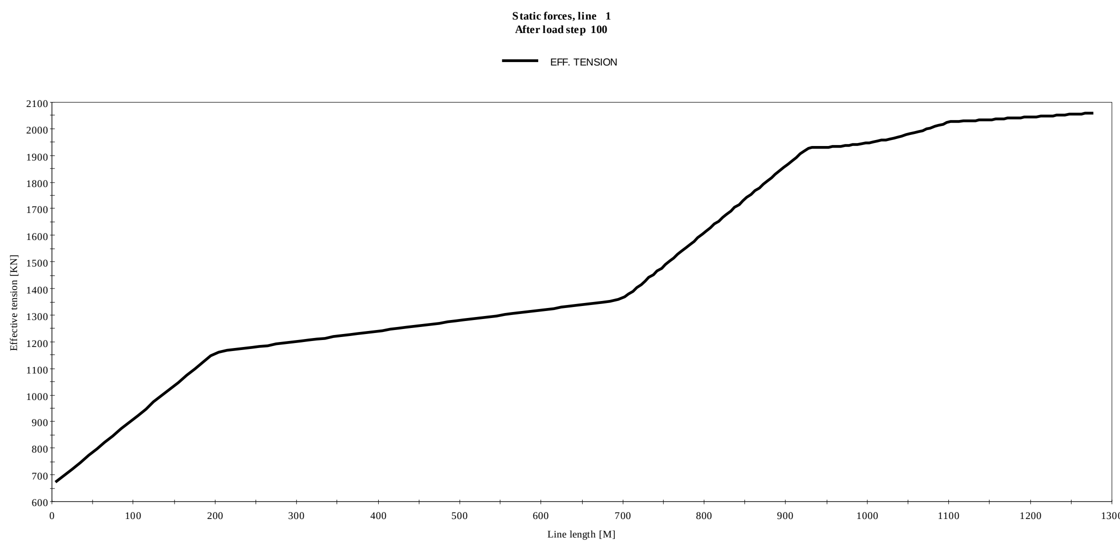

Displacement standard deviation, line 1
X
Y
Z
Standard deviation [M]
Line length [M]

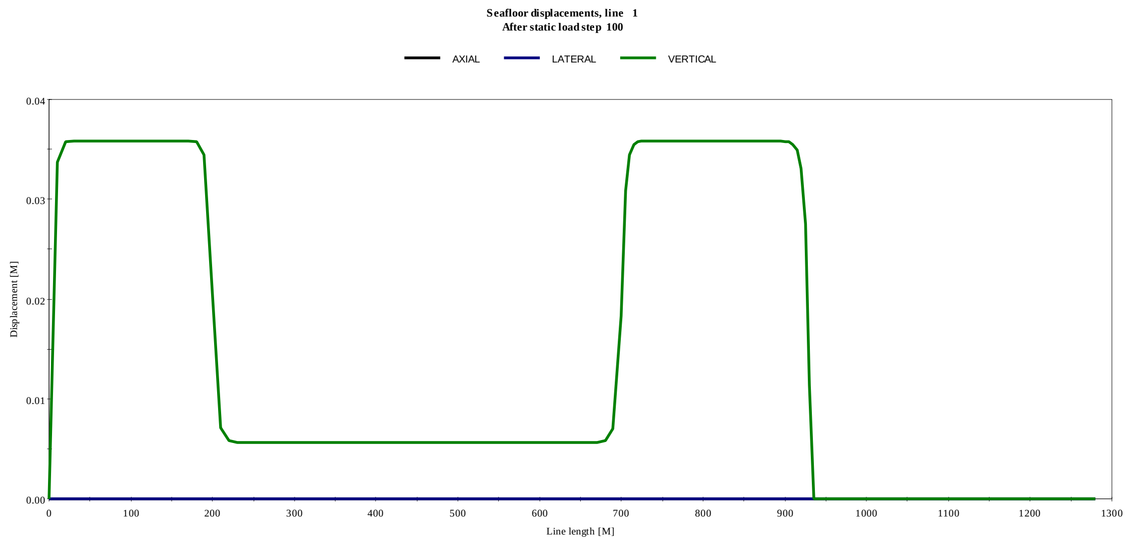

Force envelope curve, line 1
Total min and max values
F-MIN
F-MAX
[KN]
Line length [M]

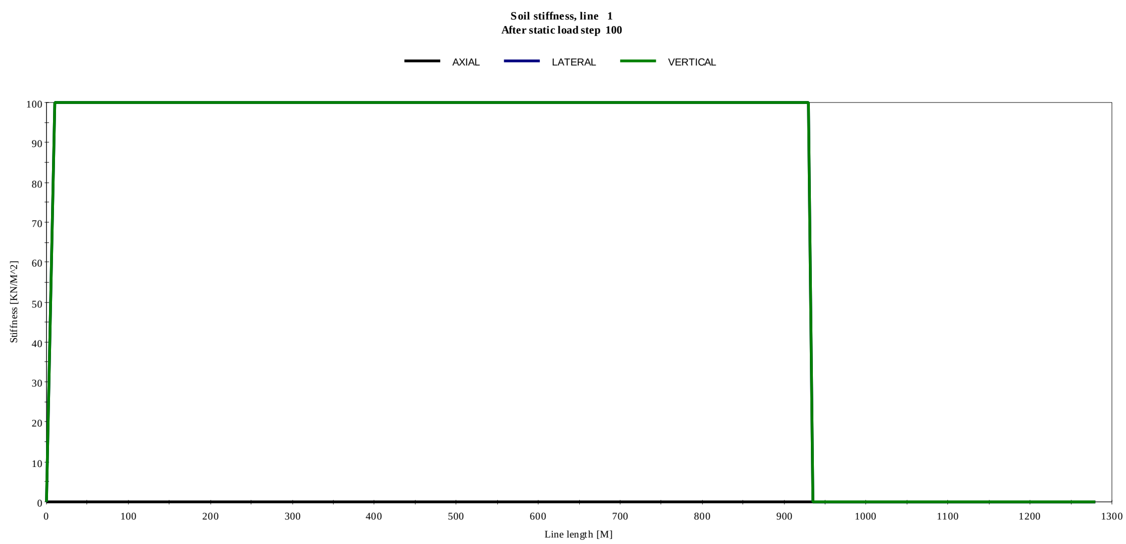

Force standard deviation, line 1
EFF. TENSION
Standard deviation [KN]
Line length [M]

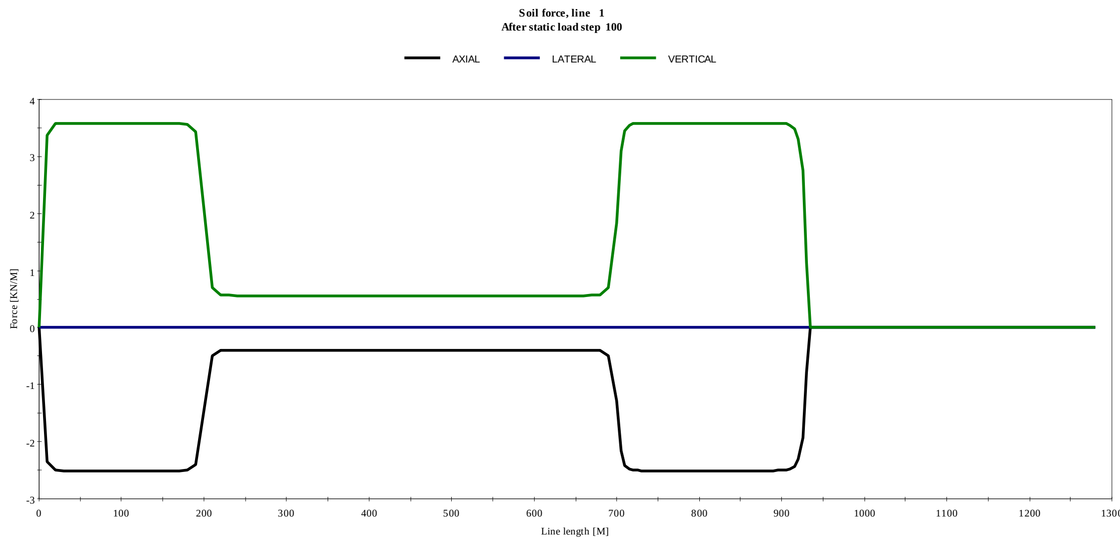
Case 1- water depth 100m
Ballasted – tension 15%MBL (2070KN) - H=30m, Period 14s

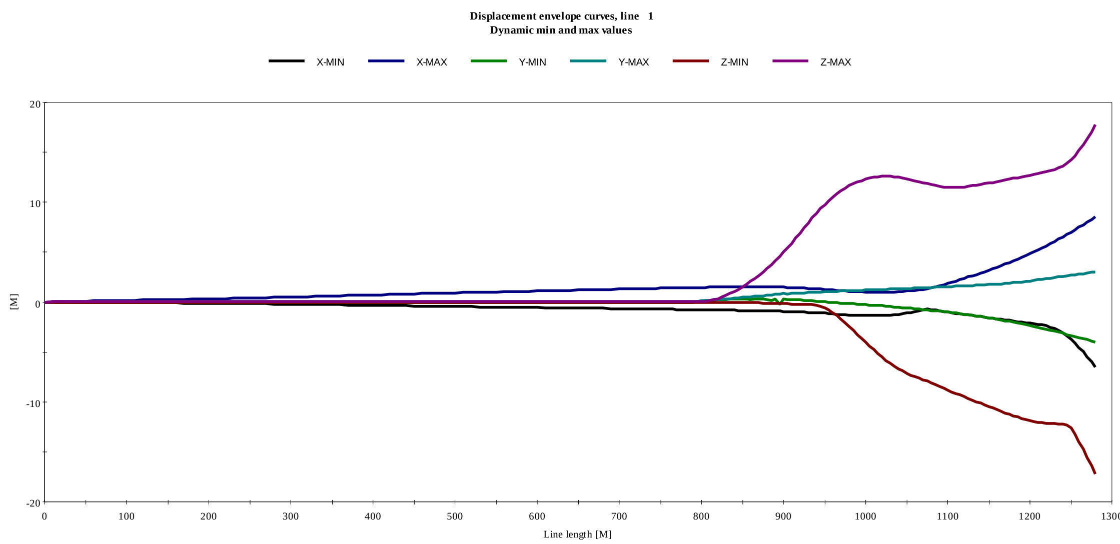


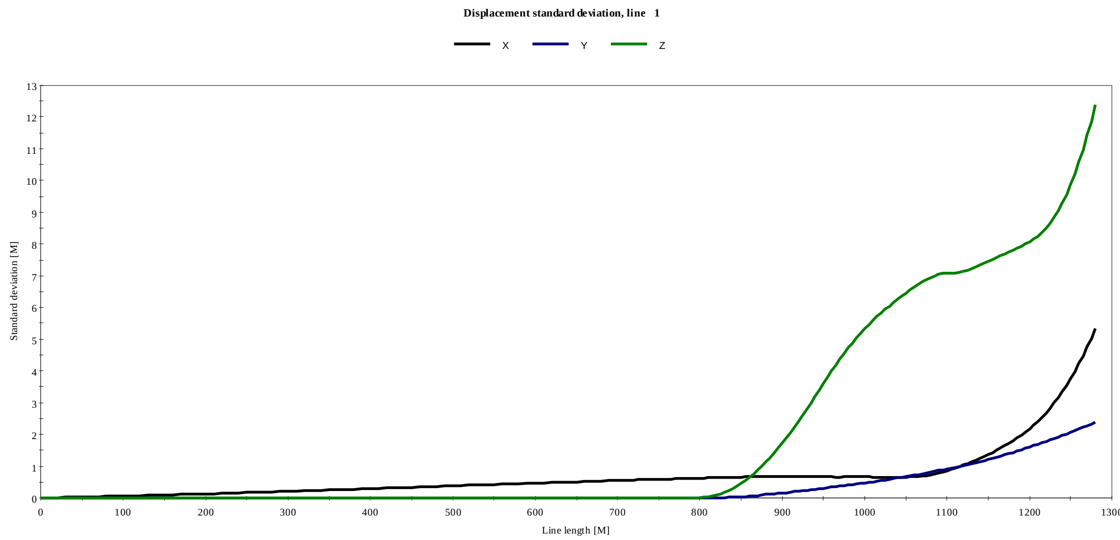


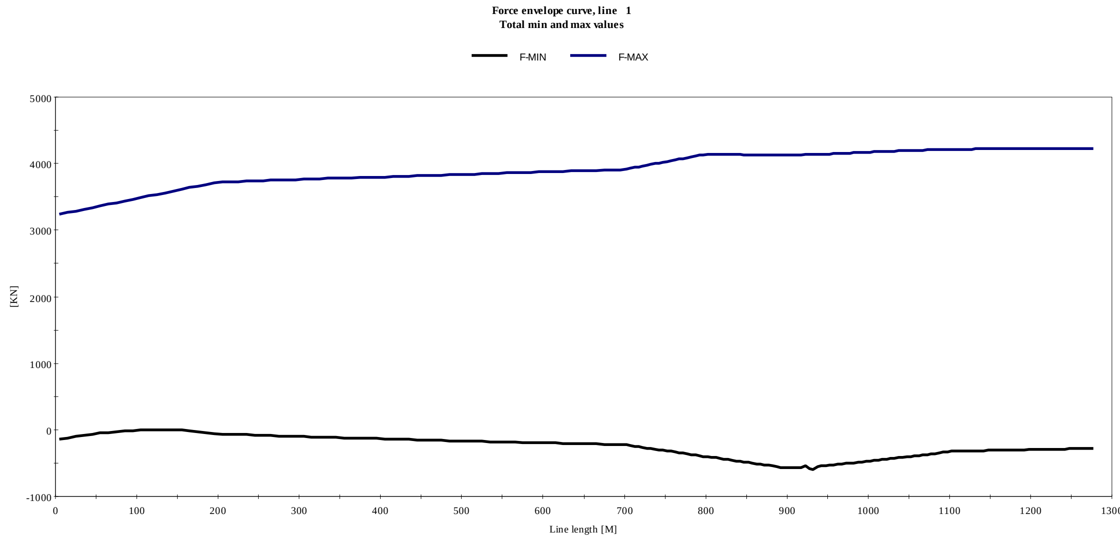

Seafloor displacements, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Displacement [M]
Line length [M]

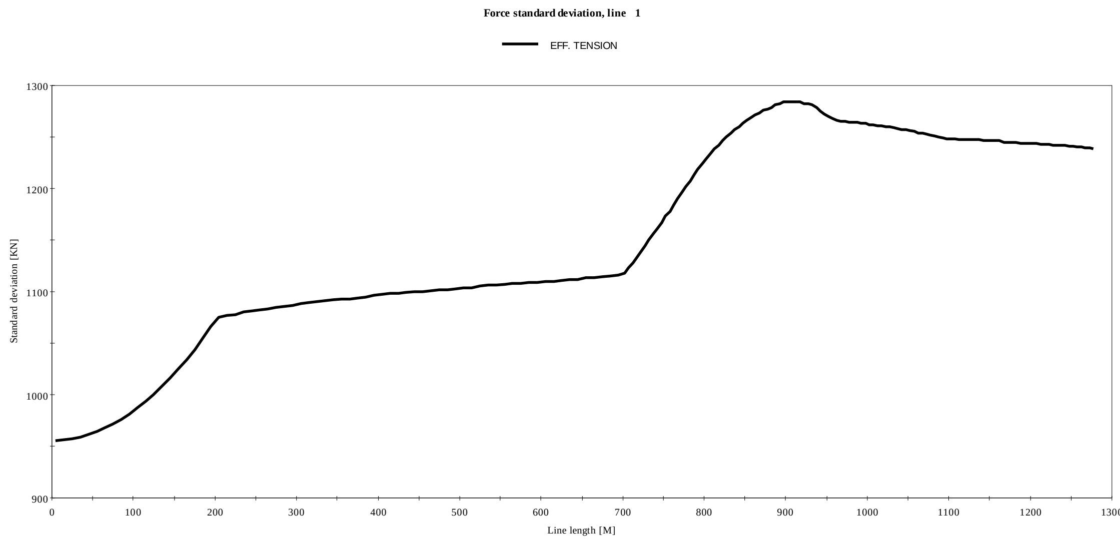

Soil stiffness, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Stiffness [KN/M^2]
Line length [M]


Soil force, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Force [KN/M]
Line length [M]

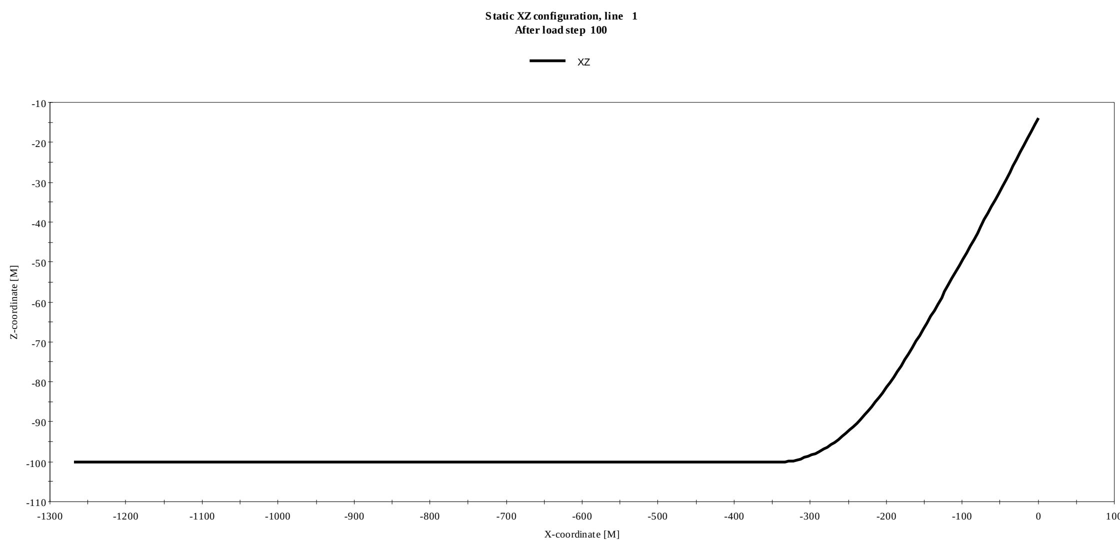

Displacement envelope curves, line 1
Dynamic min and max values
X-MIN
X-MAX
Y-MIN
Y-MAX
Z-MIN
Z-MAX
[M]
Line length [M]

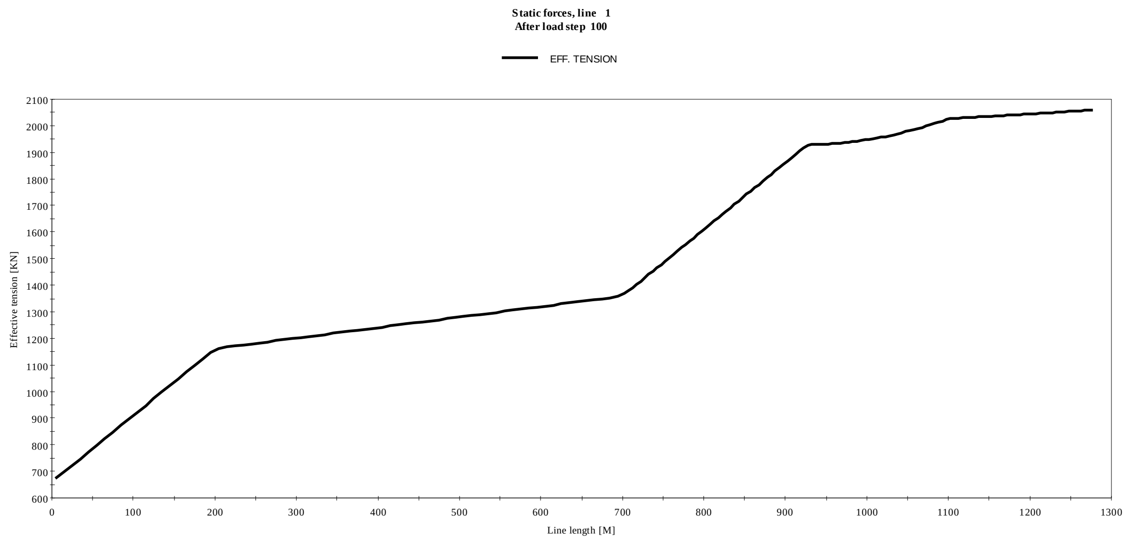

Displacement standard deviation, line 1
X
Y
Z
Standard deviation [M]
Line length [M]

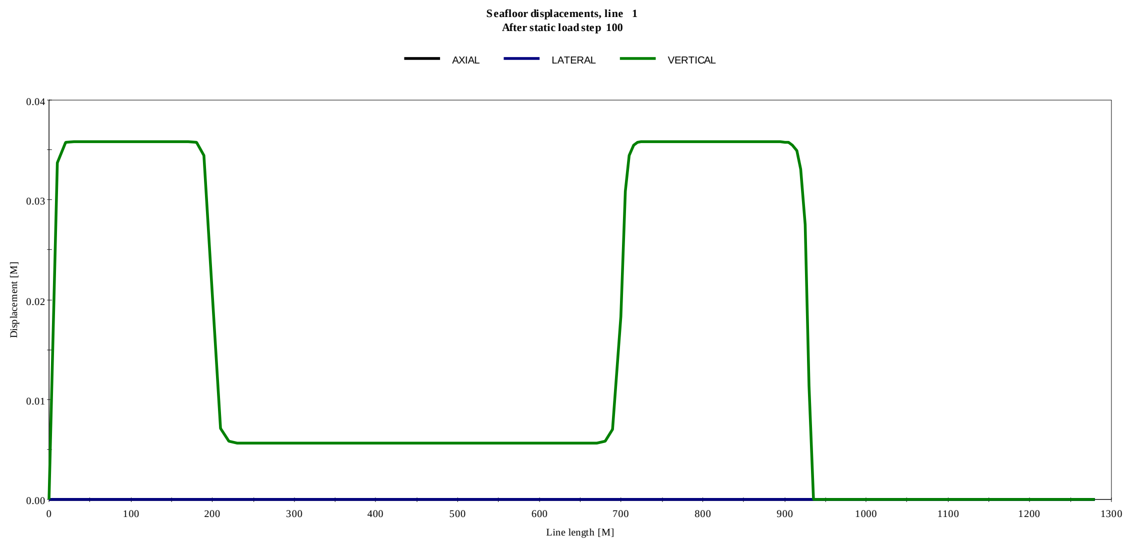

Force envelope curve, line 1
Total min and max values
F-MIN
F-MAX
[KN]
Line length [M]

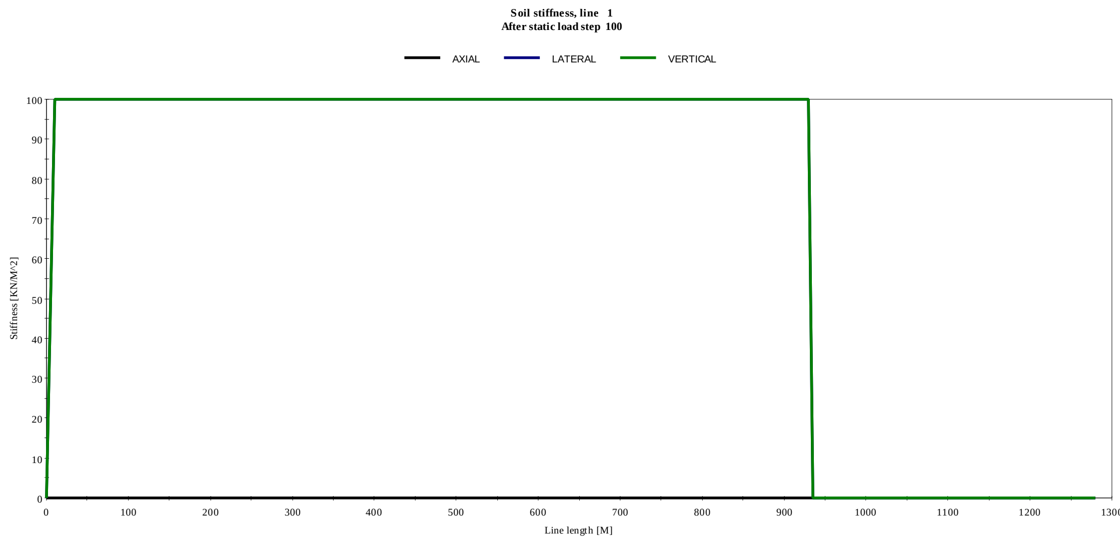


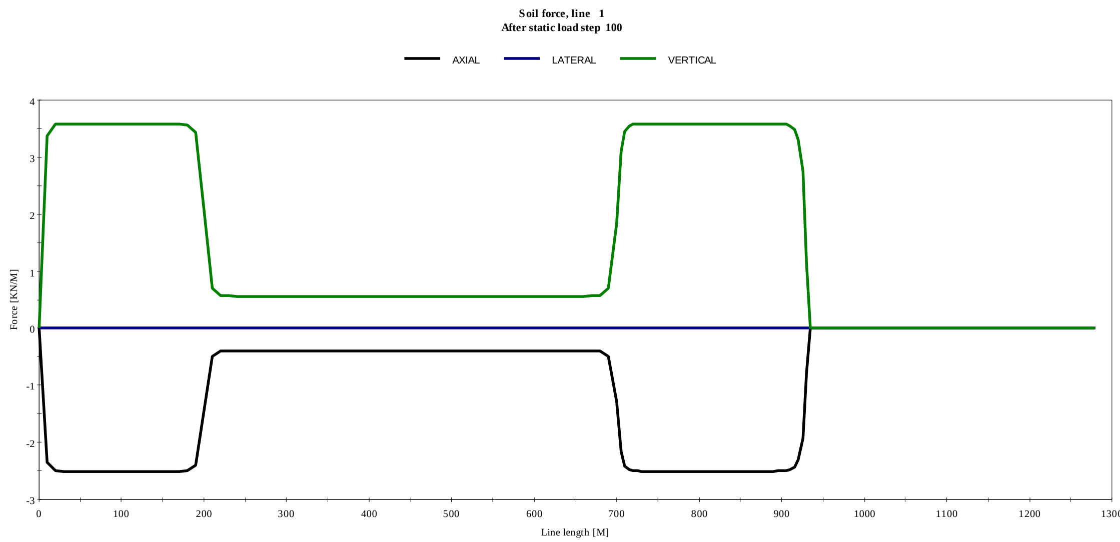
Case 1- water depth 100m
Ballasted – tension 15%MBL (2070KN) - H=30m, Period 15s

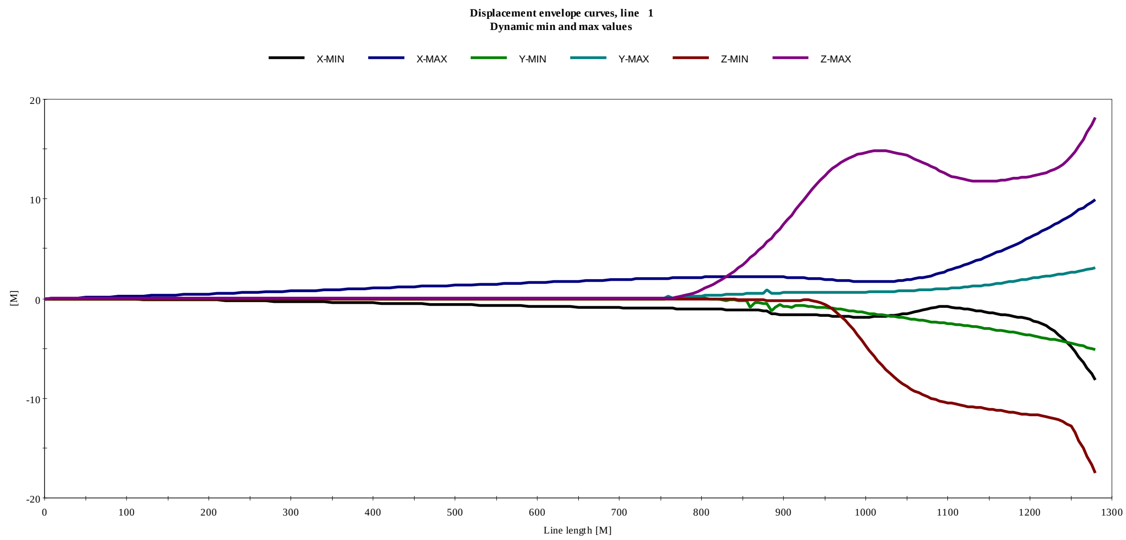


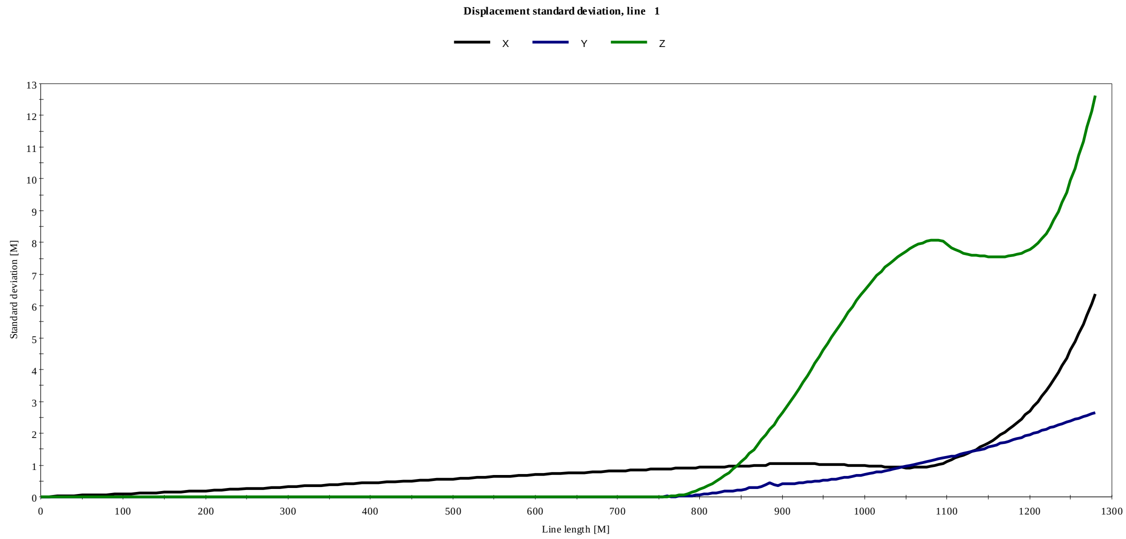

Static forces, line 1
After load step 100
EFF. TENSION
Effective tension [KN]
Line length [M]

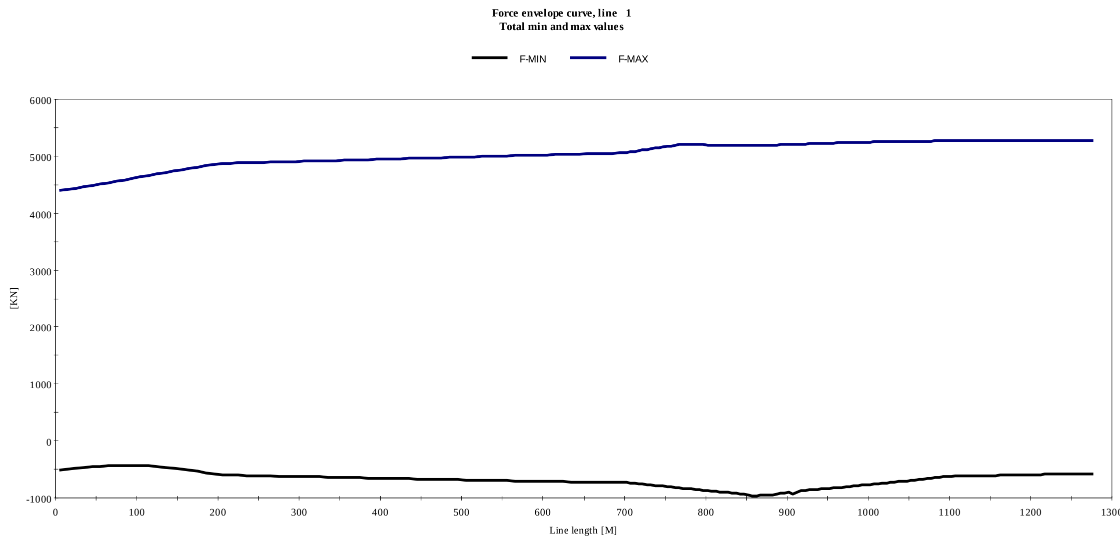

Seafloor displacements, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Displacement [M]
Line length [M]

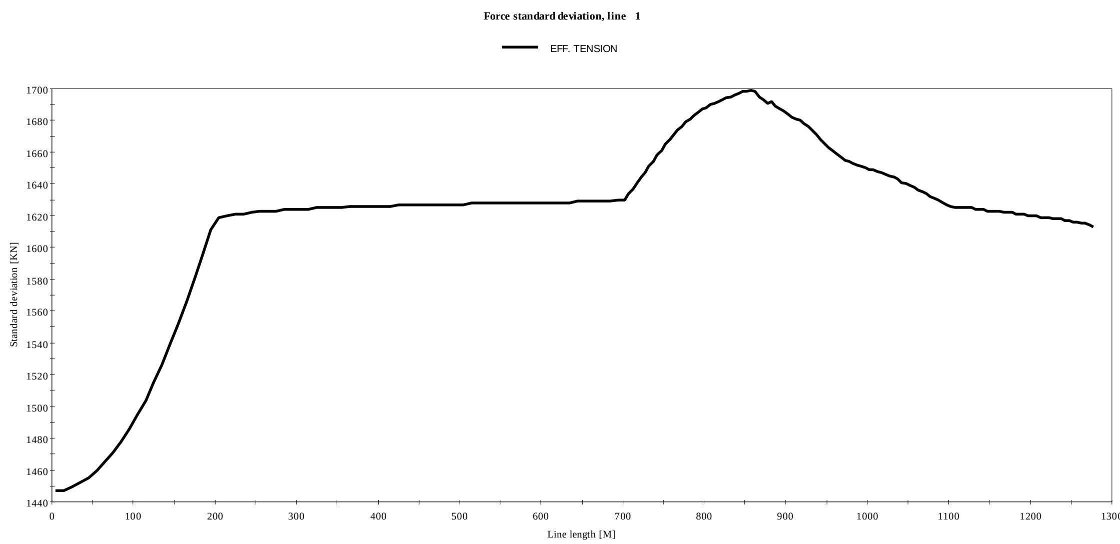

Soil stiffness, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Stiffness [KN/M^2]
Line length [M]


Soil force, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Force [KN/M]
Line length [M]

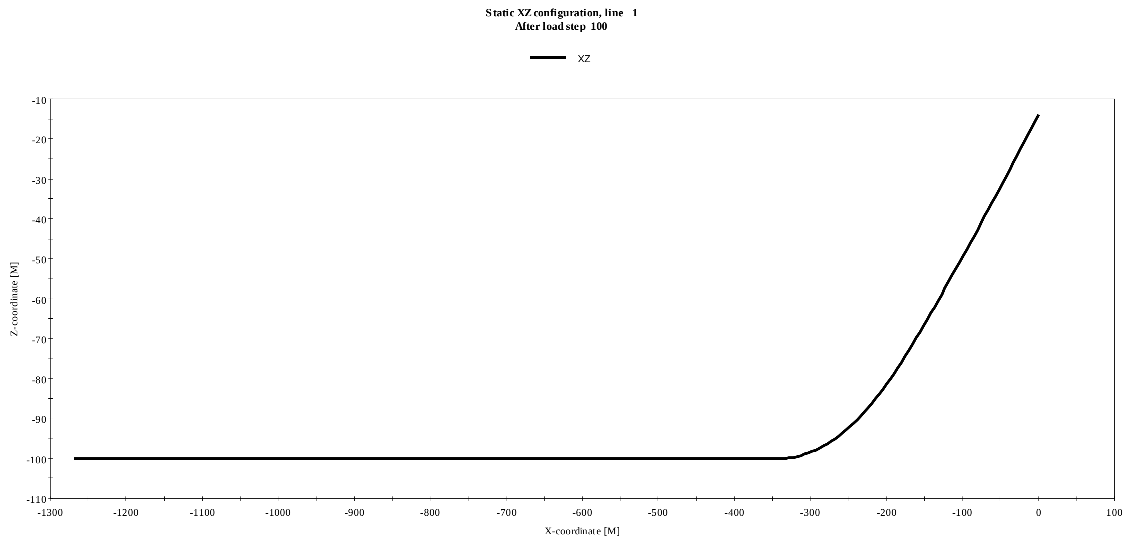

Displacement envelope curves, line 1
Dynamic min and max values
X-MIN
X-MAX
Y-MIN
Y-MAX
Z-MIN
Z-MAX
[M]
Line length [M]

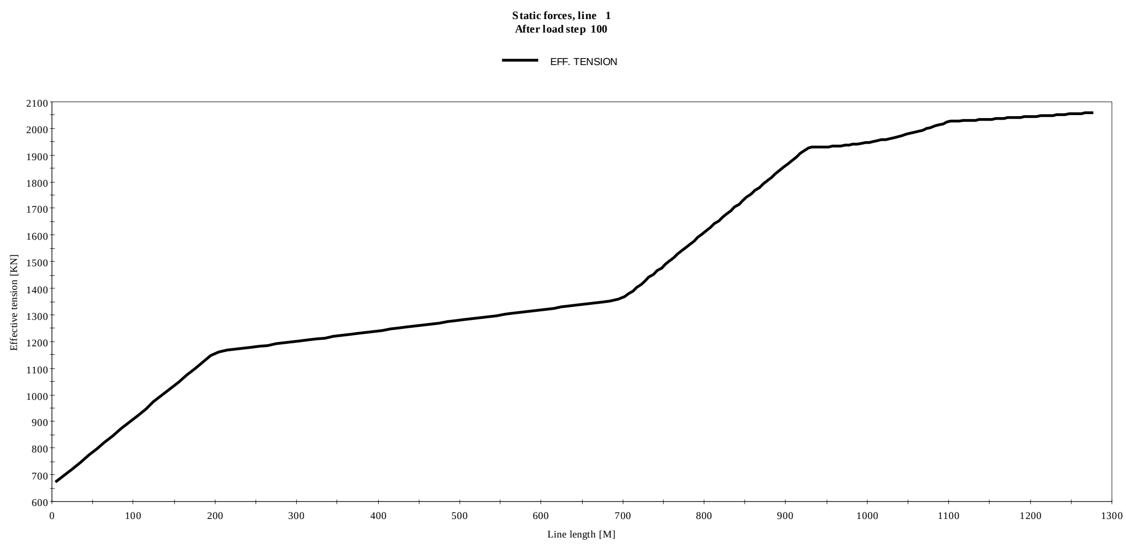

Displacement standard deviation, line 1
X
Y
Z
Standard deviation [M]
Line length [M]

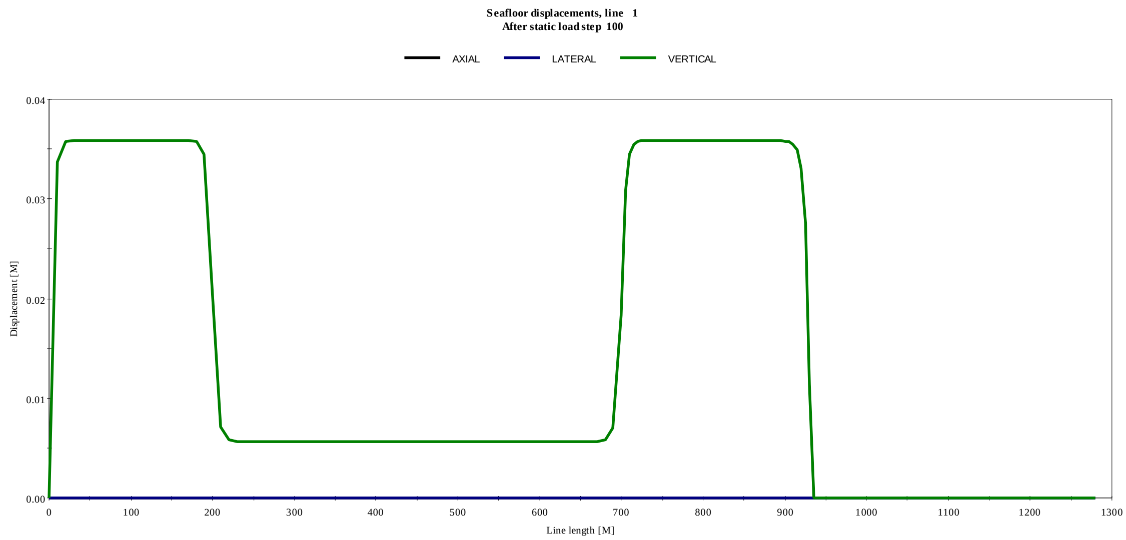

Force envelope curve, line 1
Total min and max values
F-MIN
F-MAX
[KN]
Line length [M]

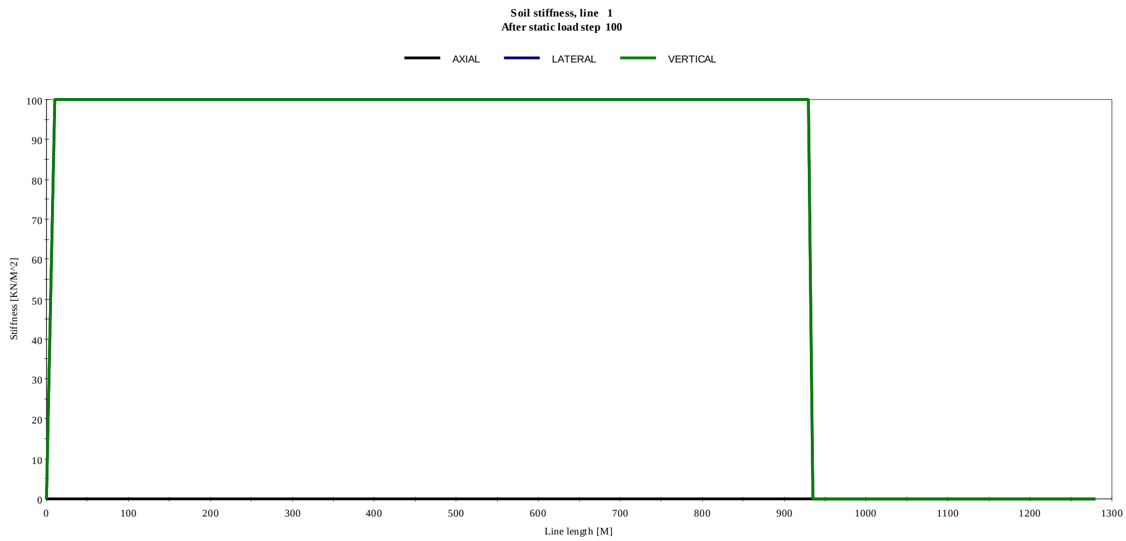

Force standard deviation, line 1
EFF. TENSION
Standard deviation [KN]
Line length [M]

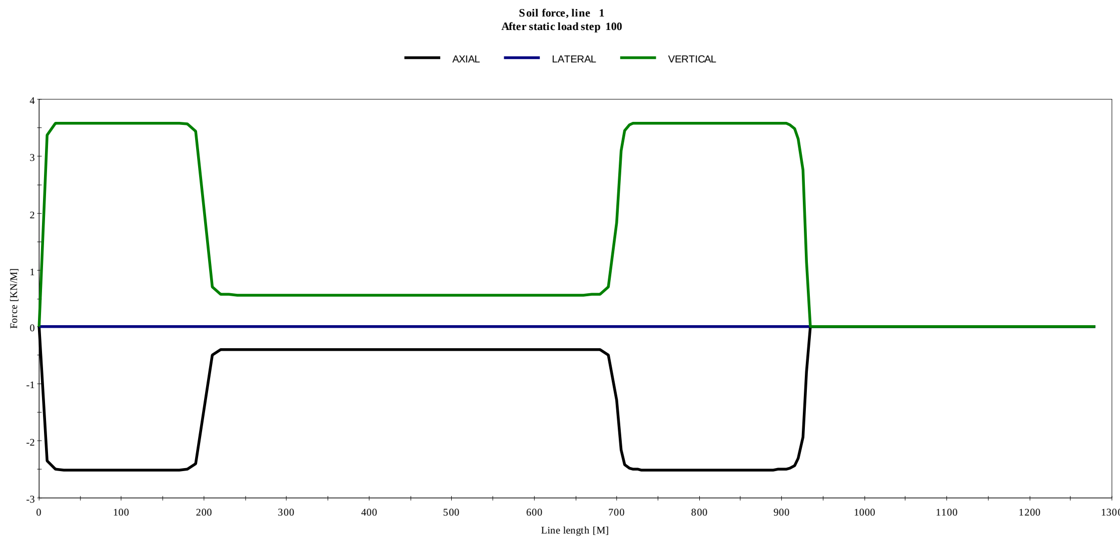
Case 1- water depth 100m
Ballasted – tension 15%MBL (2070KN) - H=30m, Period 16s

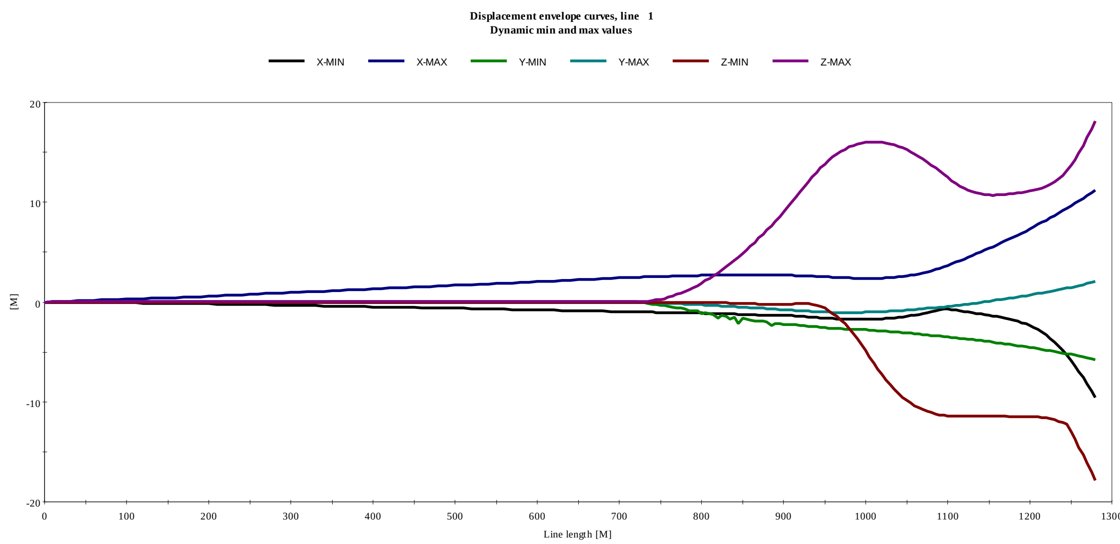


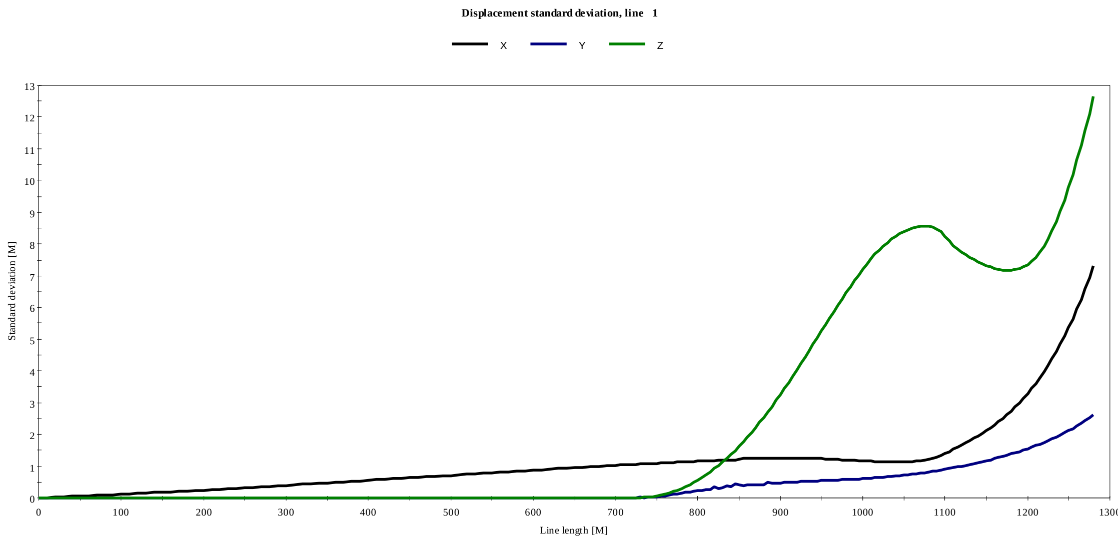


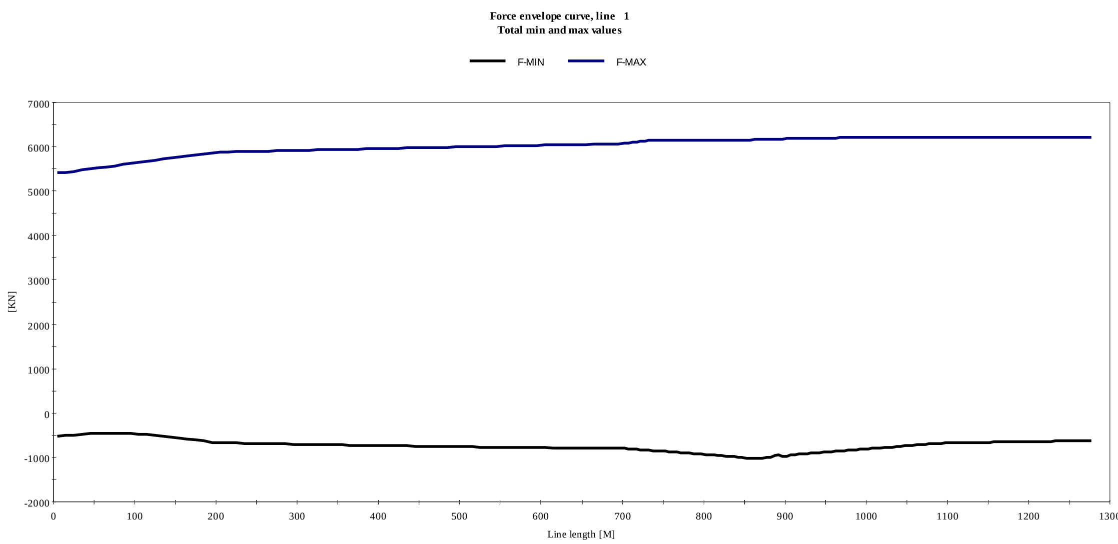

Seafloor displacements, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Displacement [M]
Line length [M]

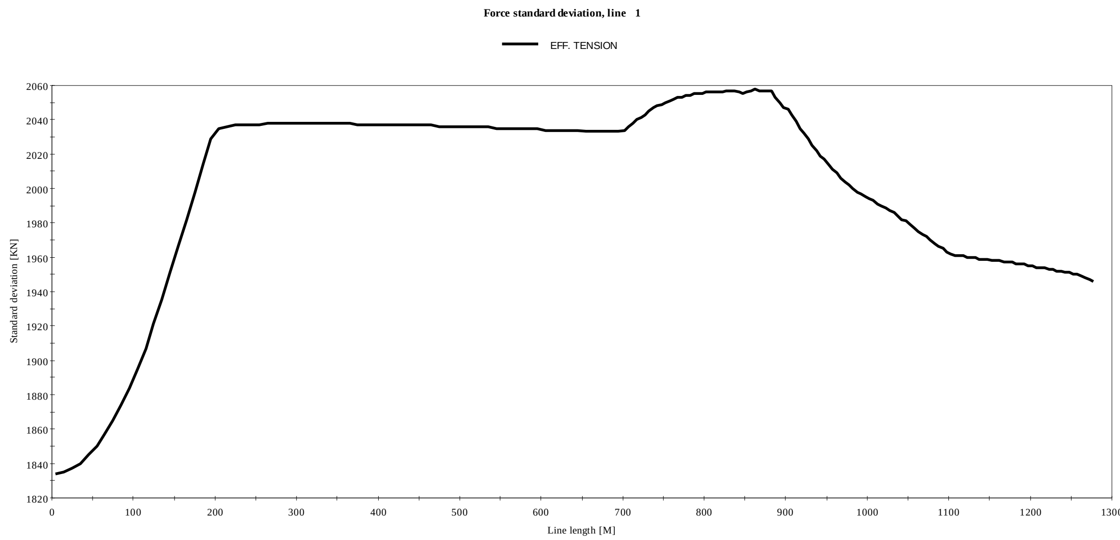

Soil stiffness, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Stiffness [KN/M^2]
Line length [M]


Soil force, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Force [KN/M]
Line length [M]

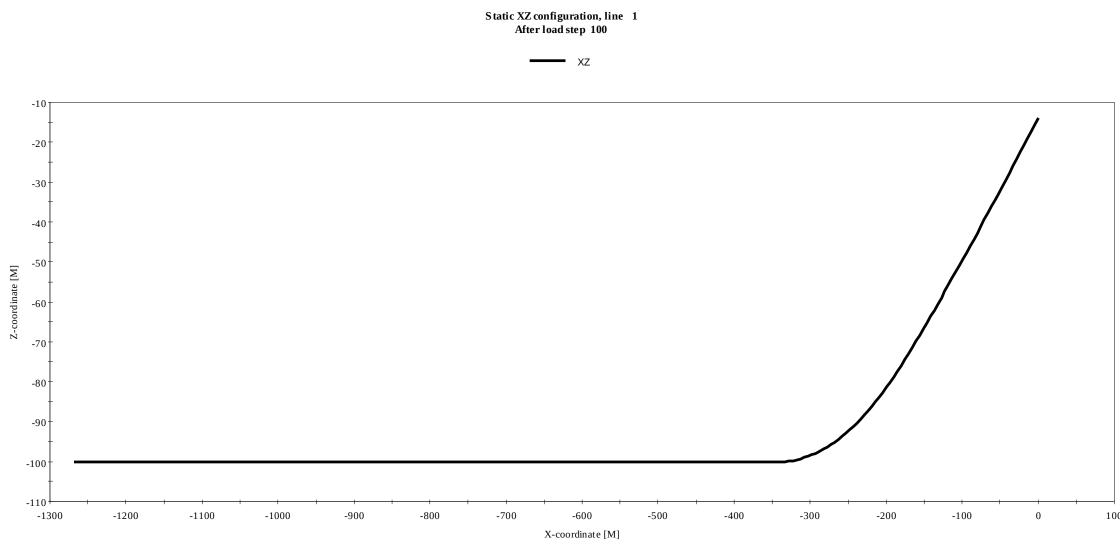

Displacement envelope curves, line 1
Dynamic min and max values
X-MIN
X-MAX
Y-MIN
Y-MAX
Z-MIN
Z-MAX
[M]
Line length [M]

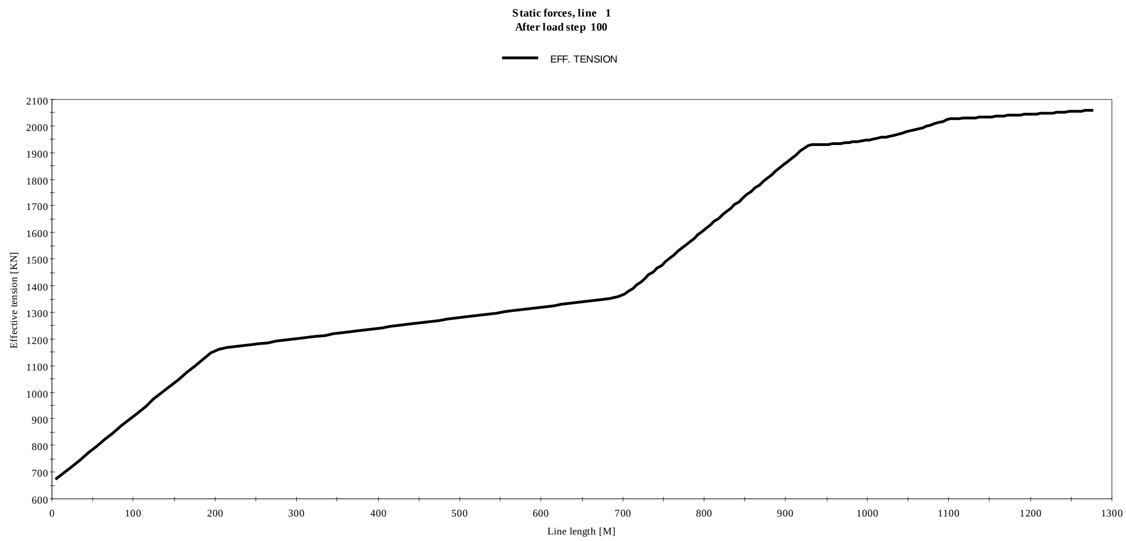

Displacement standard deviation, line 1
X
Y
Z
Standard deviation [M]
Line length [M]

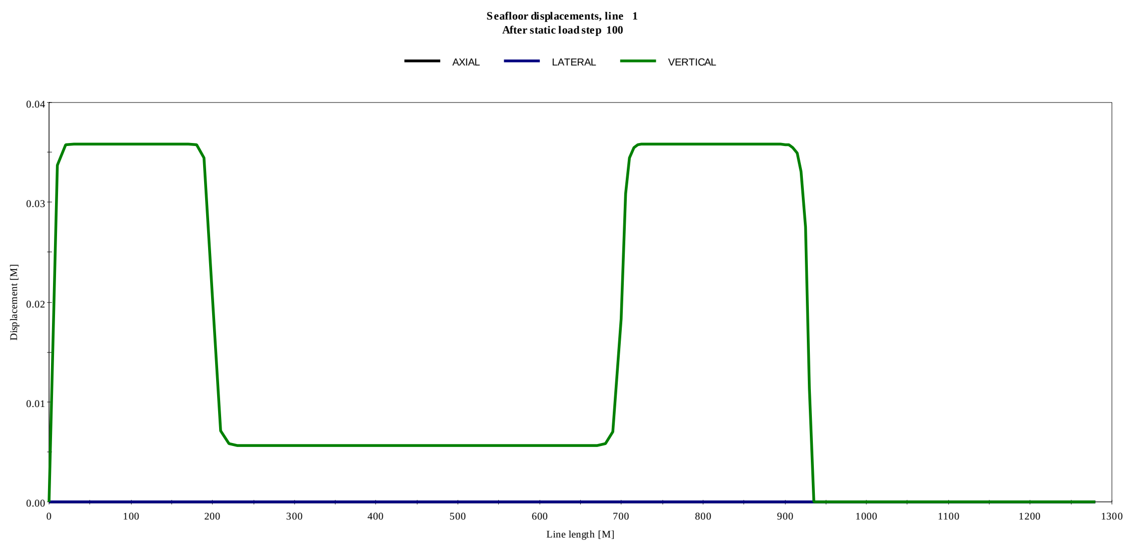

Force envelope curve, line 1
Total min and max values
F-MIN
F-MAX
[KN]
Line length [M]

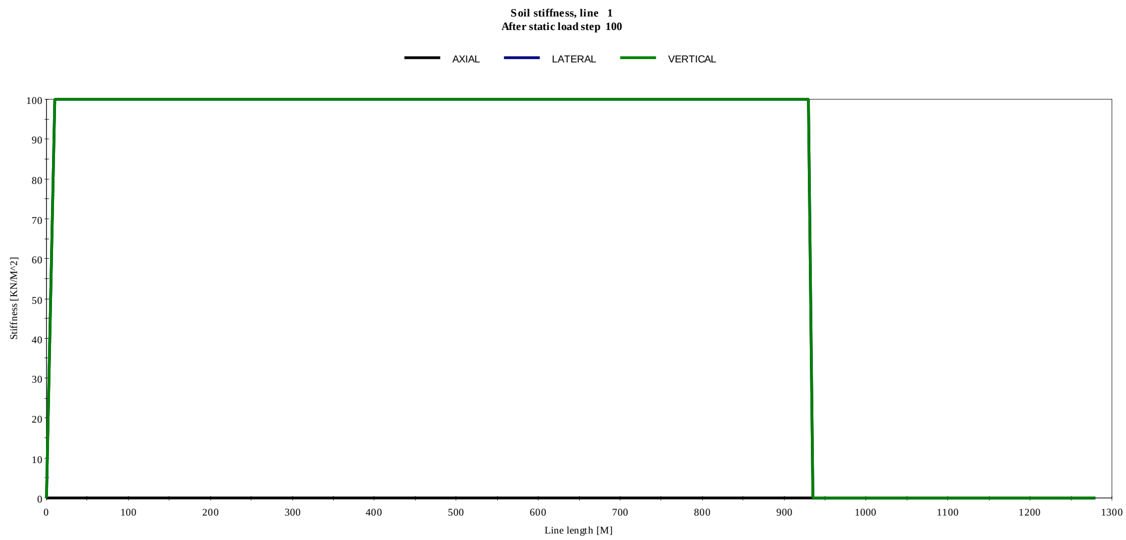


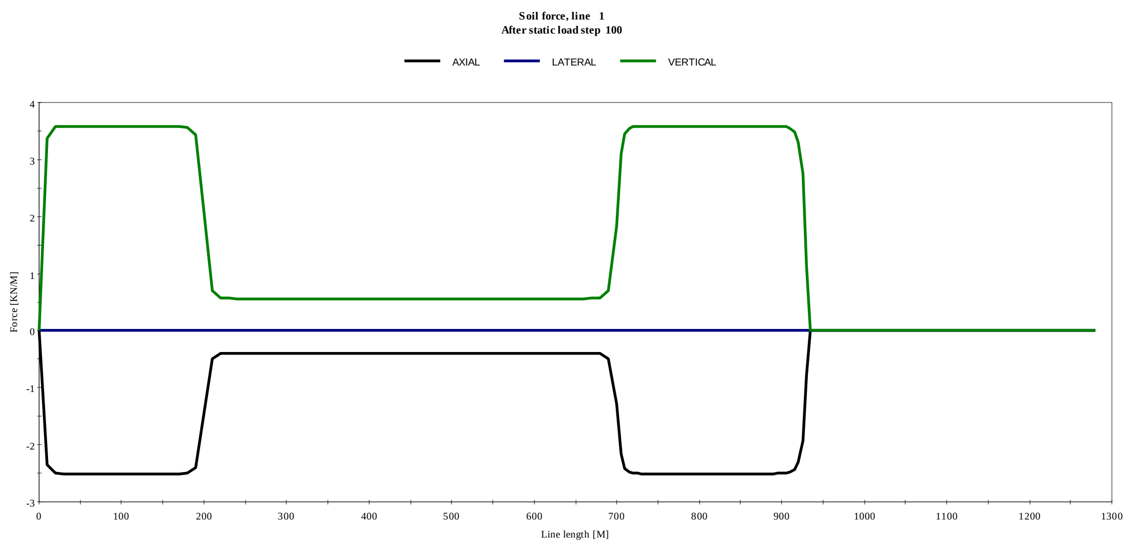
Case 1- water depth 100m
Ballasted – tension 15%MBL (2070KN) - H=30m, Period 17s

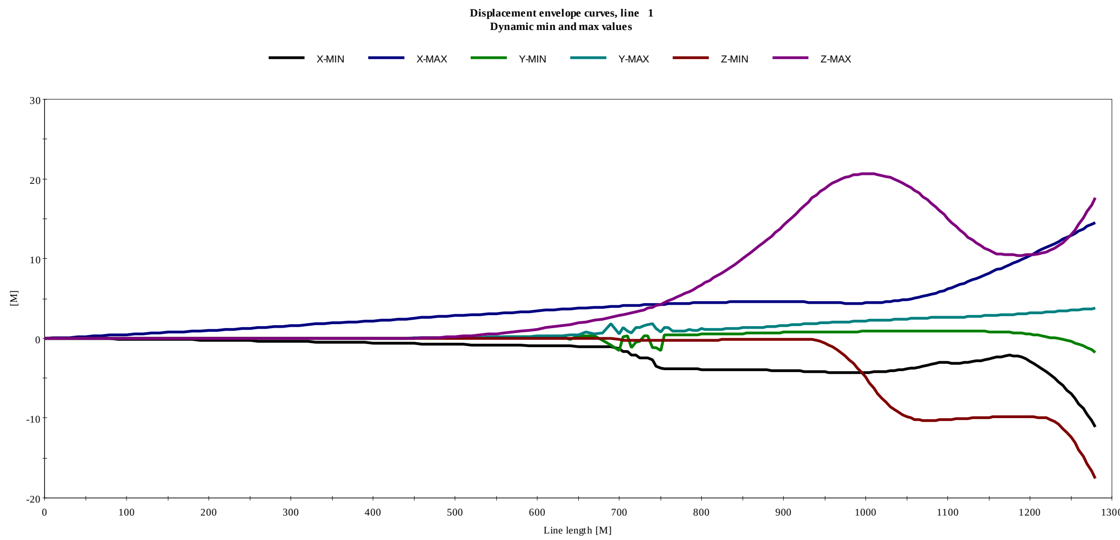


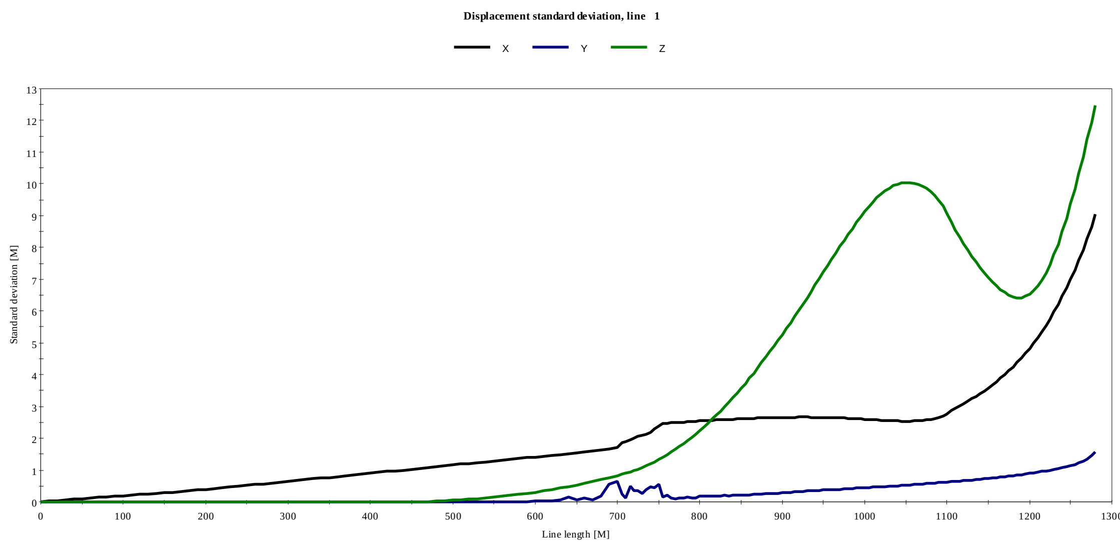

Static forces, line 1
After load step 100
EFF. TENSION
Effective tension [KN]
Line length [M]

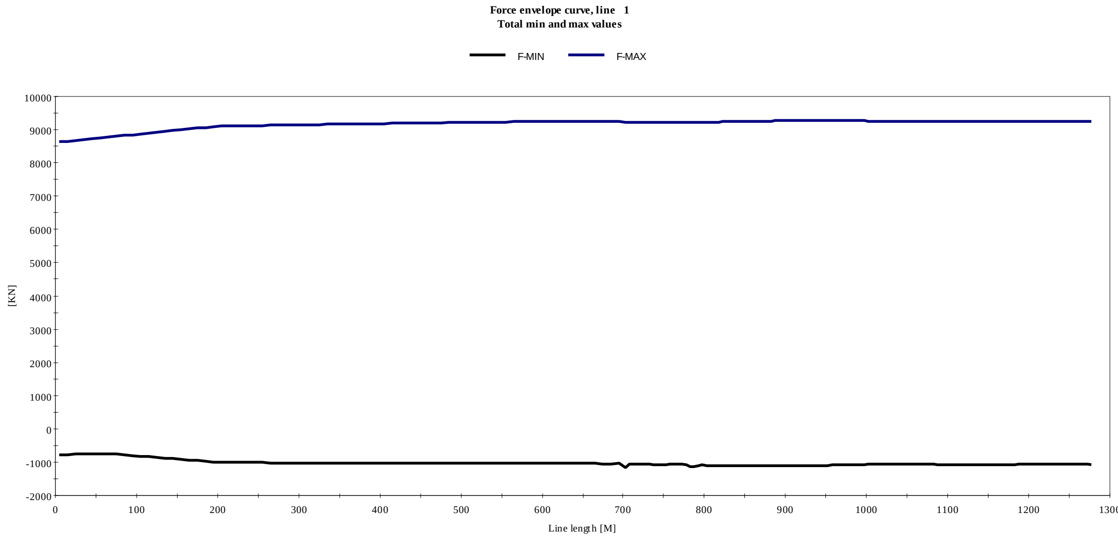

Seafloor displacements, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Displacement [M]
Line length [M]

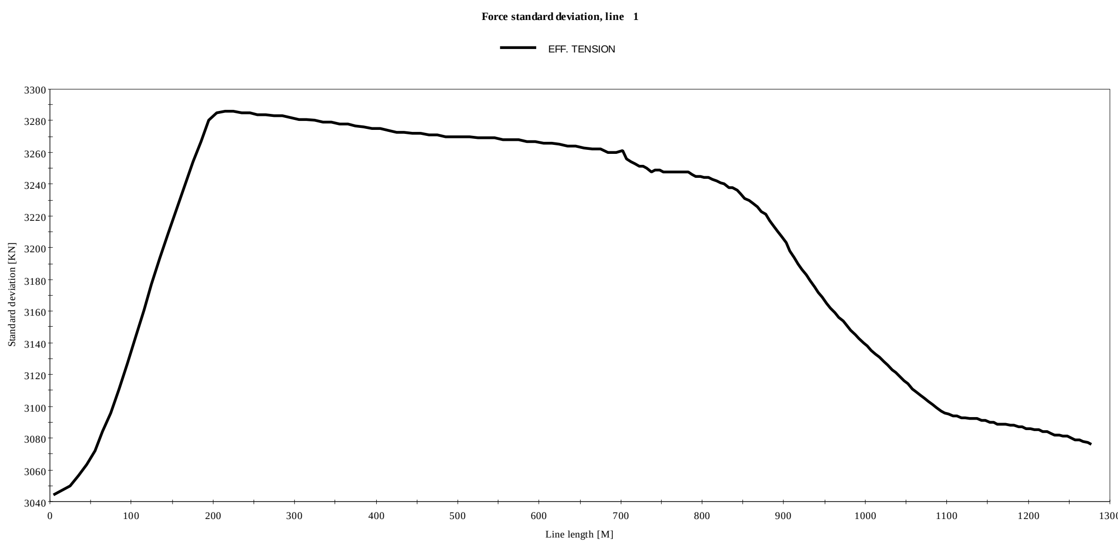

Soil stiffness, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Stiffness [KN/M^2]
Line length [M]


Soil force, line 1
After static load step 100
AXIAL
LATERAL
VERTICAL
Force [KN/M]
Line length [M]


Displacement envelope curves, line 1
Dynamic min and max values
X-MIN
X-MAX
Y-MIN
Y-MAX
Z-MIN
Z-MAX
[M]
Line length [M]


Displacement standard deviation, line 1
X
Y
Z
Standard deviation [M]
Line length [M]


Force envelope curve, line 1
Total min and max values
F-MIN
F-MAX
[KN]
Line length [M]


Force standard deviation, line 1
EFF. TENSION
Standard deviation [KN]
Line length [M]