Exploring alternatives of the mooring process of Suezmax tankers.

A lean principles approach

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Abstract

The Suezmax tankers are rather large in physical sizes, requiring skilled ship and terminal crew to execute the time consuming and, hazardous mooring process of securing the Suezmax tanker to a jetty to load or discharge oil cargoes. New mooring equipment technologies have emerged, enabling the industry professionals to view the mooring process with a different perspective. Lean perspectives adopted from the car manufacturer Toyota have been applied in this thesis to give depth and critical view of different perspectives of mooring process of Suezmax tankers.

A single case study with a holistic design has been done to respond to the two research questions in this thesis. The first research question concerns the mooring itself: what is the mooring process of Suezmax tankers? This is followed by the second question: how can the mooring process of Suezmax tankers be improved?

The major findings are that mooring is a complex task, involving both ship and terminal crew, who are at risk of getting injured both during maintenance work and during the mooring process. A time saving potential of about 30 min is identified when changing from steel mooring wire line to HMSF (High Modulus Synthetic Fibre) mooring line. A further time saving potential is identified if the mooring process is reengineered, reducing the required number of ship and terminal crew needed to perform the mooring process, enhancing the safety aspect of the Suezmax tanker mooring process.

Keywords: Lean, ship safety, Suezmax tanker, mooring process, mooring lines

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Glossary

Glossary word is defined by OCIMF (2018), except for words that have source specified in brackets.

Abrasion resistance: The ability of a fibre or rope to withstand surface wear and rubbing due to motion against other fibres of rope components (internal abrasion) or a contact surface such as a fairlead (external abrasion).

Aramid: A manufactured fibre consisting of very long molecular chains formed by rearranging the structure of aromatic polyamides.

Bitts: Vertical steel posts or bollards, mounted in pairs, around which a line can be secured.

Bollard: A vertical post ashore to which the eye of a mooring line can be attached.

Brest lines: Mooring lines leading ashore as nearly perpendicular as possible to the ship`s fore and aft line.

Deadweight (DWT): The carrying capacity of a ship, including cargo, bunkers and stores, in metric tonnes. It can be given for any draught but in this instance, it is used to indicate summer deadweight at summer draught.

Dolphin: An independent platform incorporating mooring hooks or bollards for securing ship`s mooring lines. It may also incorporate mooring fenders such as breasting dolphins.

Elasticity: The elastic (non-permanent) elongation of a unit length of an element caused by a unit load. May refer to a material or composite structure such as a mooring line.

Elongation: The total extension (elastic and plastic) of a line.

Fairlead: A guide for a mooring line that enables the line to be passed through a ship`s bulwark or other barrier, or to change direction through a congested area without snagging or fouling. Also known as a chock.

Fatigue: The tendency of a material to weaken or fail during alternate tension-tension or tension-compression cycles. Some fibres develop cracks or splits that cause failure, especially at relatively high loads.

Fibre: A long, fine, very flexible structure that may be woven, braided, stranded or twisted into a variety of fabrics, twine, cordage or rope.

First line ashore: A line put ashore first to help positioning and in hauling the ship into berth.

Head lines: Mooring lines leading ashore from the fore end of a ship, often at an angle of about 45 degrees to the fore and aft line.

Heaving line: A very light line that is thrown between the ship and the berth and used to draw a messenger line ashore.

High Modulus Synthetic Fibre: The generic term applied to a range of fibre materials.

Joining shackle: A shackle used to connect a mooring line to a synthetic tail.

Marine loading arms: Transfer units between ship and shore for discharge and loading. May be articulated all-metal arms (hard arms) or a combination of metal arms and hoses.

Messenger line: A light line attached to the end of a main mooring line and used to assist in heaving the mooring to the shore.

Mooring line: A line made of synthetic fibre or steel wire that extend from mooring points on the Suezmax tanker to mooring points on the jetty (Gaythwaite, 2014)

Mooring process: The actions required to safely secure a Suezmax tanker to a jetty. (Thoresen, 2014)

Mooring restraint: The capability of a mooring system to resist external forces on the ship.

Polyamide: The common chemical name for nylon fibre.

Retirement: To permanently remove from service.

Risk assessment: A process of reviewing the risks attached to operations such as mooring and unmooring the Suezmax tanker.

Ship design MBL: The minimum breaking load of a new, dry mooring lines for which a ship`s mooring system is designed, to meet OCIMF standard environmental criteria. The ship design MBL is the core parameter against which all the other components of a ship`s mooring system are sized and deigned with defined tolerances.

Spring lines: Mooring lines leading in a nearly fore and aft direction to maintain the longitudinal position of the ship while in a berth. Headsprings prevent forward movement and aft springs prevent aft movement.

Stern lines: Mooring lines leading ashore from the after end or poop of a ship often at an angle of about 45 degrees to the fore and aft line.

Tail: A short length of synthetic rope attached to the end of a mooring line to provide increased elasticity and ease of handling.

Terminalling: Crude oil and oil products handling and storage. of raw materials, intermediates and/or finished products. (Law Insider, 2021)

Vetting: The act of making an examination and critical appraisal of a Suezmax tanker (Collinsdictionary.com, 2021)

Value: Defined by the customer, e.g., a service enhancing the perceived worth by removing wasteful activities (Womack & Jones, 1997)

Value added: Concept whereby a service given adds value to a product or service. (Lowe, 2002)

Waste: Resources that has direct impact on cost and quality of the service not utilized to its full potential (Alukal, 2003). In this thesis the following six wastes are threated (Alukal, 2003):

Defective equipment e.g., inspection, replacement, or repair.

Overprocessing e.g., maintenance of equipment.

Waiting e.g., for the ship and terminal crew, machinery, or information.

People e.g., not using their full mental, creative skills and experiences.

Motion e.g., ship crew working on mooring lines, mooring line boats transferring mooring line, etc

Transportation e.g., mooring lines transported to storage or brought out from storage and installed to mooring winches. Equipment needed for maintenance tasks.

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1 Introduction

"A transport system is designed so that its parts work together as efficiently as possible, and sea transport is just one stage in the transport chain…" (Stopford, 2009, p. 422).

Transport, playing a vital role in logistics and supply chain management activities, also has a crucial place within international trade as trade cannot get into action without the movement of the goods from one point to another. (Song & Panayides, 2012, p. 25).

Maritime transportation is accounting for about 85 % of international trade (Song & Panayides, 2012, p. 23). UNCTAD (United Nations Conference on Trade and Development) (2018) reports a total of goods loaded on ships in year 2017 to 10 702 million tons, and out of that figure, 1 875 million tons are crude oil. The crude oil is used in a wide variety of products and forms, and as Claksons, (2018) put it: *"Petroleum products power our vehicles and planes, heat our homes, run our factories, and form the basis for the plastics that go into a vast range of consumer and industrial products."*

Crude oil is normally transported in purpose-built ships, and the size of the ships is dependent at the distance the goods is to be transported. The largest ships transport the largest quantities over the longest distances, whereas the smaller ships are between smaller regions.

Table 1. Overview of typical crude oil tankers in service today

Type of tanker	Size Range	Typical Length
Very Large Crude Carrier	295 000 – 320 000 DWT	333 m
Suezmax	145 000 – 165 000 DWT	274 m
Aframax	95 000 – 120 000 DWT	244 m
Panmax	65 000 – 75 000 DWT	228 m

Source: Clarksons, 2019, Compiled by the author

A paramount factor in the maritime transport, is successful mooring of the tankers to terminals and refineries to allow for safe and efficient transfer of cargo. Hence, mooring process, as well as ways to improve them, are highly relevant. The author has been working 12 years in the Suezmax tanker business, and performed numerous loadings, transport, and discharge of crude oil to terminals and refineries. An area which the author really paid attention too is the mooring process. A vast amount of resources are needed for the maintenance, preparation, deployment, and monitoring of the mooring system during port stay. Further, there are many types of errors that can occur, which may put ship and terminal crew in danger, as well as cause damage to ship and terminal property. The authors` experience from the Suezmax tanker business is mixed with the new thoughts and ideas which were acquired during the authors study at the master in maritime management at the University of South-Eastern Norway through subjects such as innovation projects, maritime economics, and supply chain management. The research questions in this thesis are focused on the mooring process, keeping in mind the words (OCIMF.org, 2020): "*Mooring process is one of the most complex and dangerous operations for ship and terminal crew. If something goes wrong, the consequences can be severe*." See chapter 2.4 for more details of mooring process, and Chapter 3.3 for a case description of the mooring process

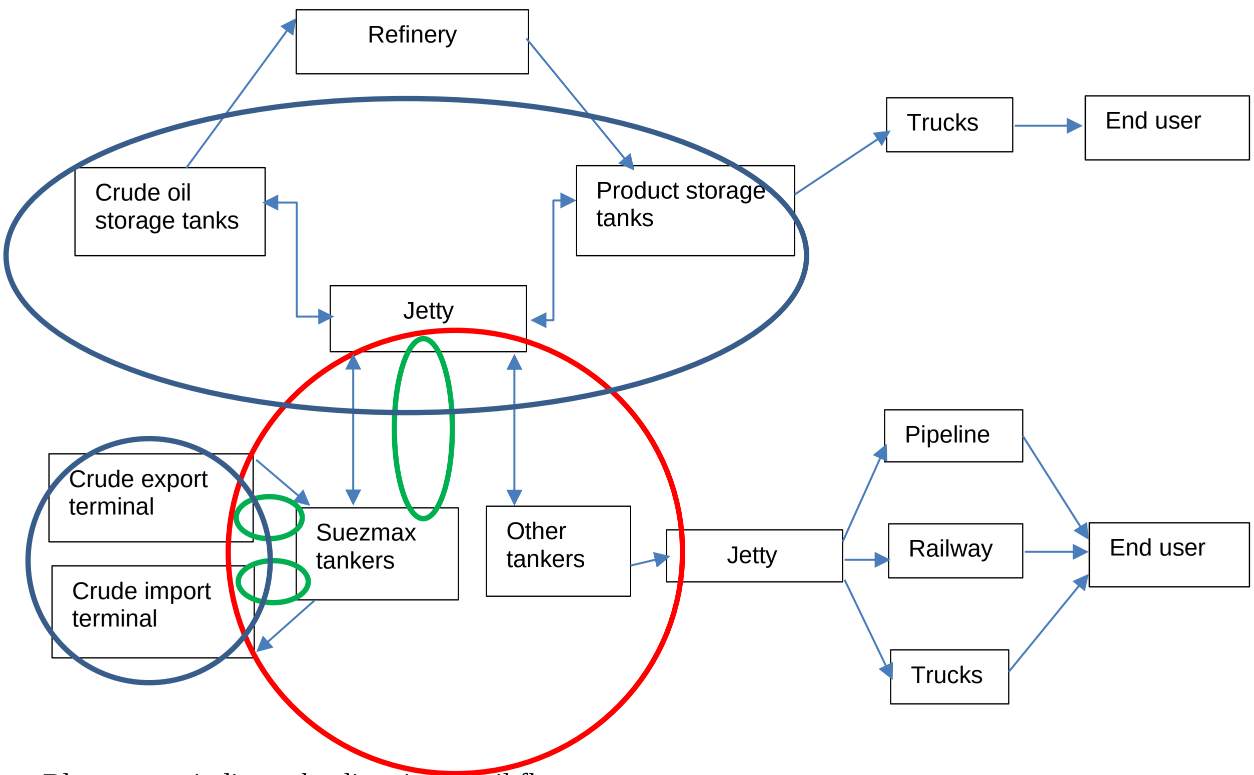
The research questions are:

Q1: What is the mooring process of Suezmax tankers?

Q2: How can the mooring process of Suezmax tankers be improved?

Figure 1.

Suezmax tankers whereabouts in the logistic chain of oil and oil product movement.



Blue arrows indicate the direction of oil flow.

Rectangular boxes are filled with text to indicate purpose.

Red circle indicate the marine transportation of oil and oil products.

Blue circle and eclipse are indicating terminalling (Law Insider, 2021) of crude oil and oil products.

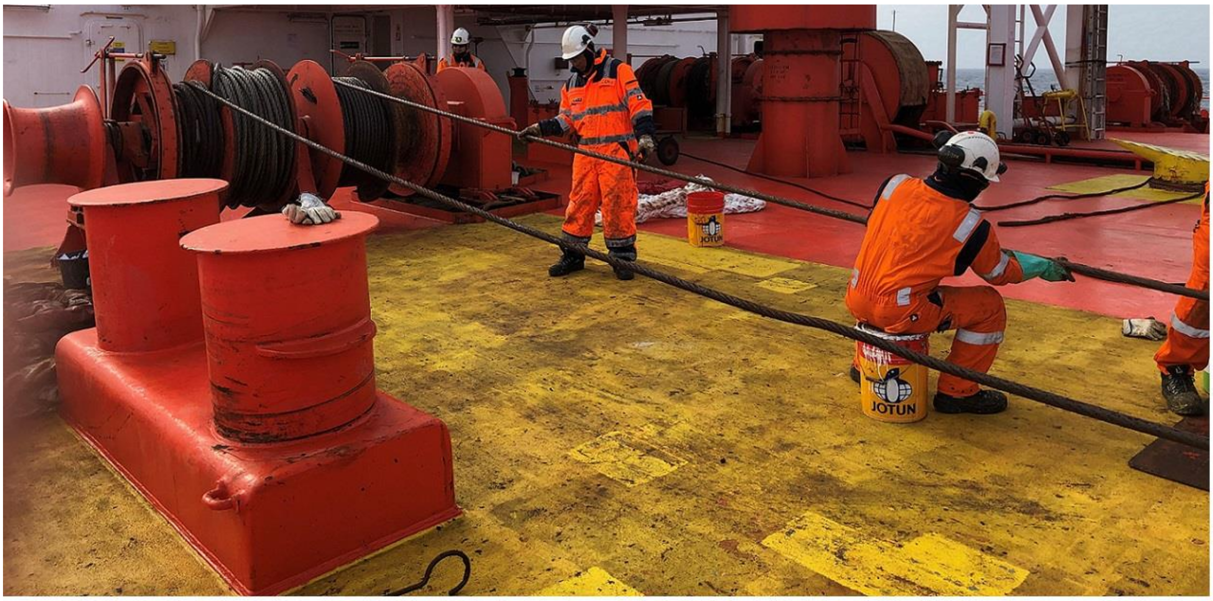
Green circles are indicating the mooring process studied in this thesis. See Figure 2 in Chapter 3.3 for further illustration of the mooring process.

Other tankers are not part of this thesis but are included in the figure to illustrate that other types of crude and petroleum products tankers are utilized at the same jetties as Suezmax tankers. See Table 1 in Chapter 1 for dimensions of typical crude oil tankers.

Each move of crude oil with Suezmax tankers requires the mooring process to be performed twice, when the Suezmax tanker is loading (bringing cargo onboard) and then again when discharging (bringing cargo ashore).

Source: Based on Figure 2.9 in Stopford (2009, p.82) elaborated by the author.

Figure 3. Suezmax tanker illustration of physical dimensions, ship crew, mooring equipment, and the complexity involved of mooring line maintenance.



Source: Photograph taken by the author 15th of April 2019. The view is from portside poop deck area facing forward and to starboard, the author is located at the railing at the aftermost position on the poop deck when the photograph is taken, illustrating the ship crew are manually greasing steel mooring line located at port stern line winch. Appendix 4 is illustrating hazards of such a task.

The photograph is showing one out of two portside stern mooring wire lines being manually lubricated by four members of the ship crew in order to increase corrosion resistance. One ship crew member is controlling the winch, while the three other ship crew are applying grease to the slow running mooring line wire. In the upper right corner can the mooring winch for starboard stern line be seen, and on top in the centre is the aft breast line winch located. The yellow painted deck area is coated with anti-skid paint to increase friction between deck area and the ship crew working shoes when manually transferring mooring wire line from storage side to tension side on the mooring winch drum.

2 Literature review

This chapter is dived into six sections. The first section is a literature review on lean principles adopted from the car manufacturer Toyota and arguments for valid application in the mooring process of Suezmax tankers, in this context the mooring process is looked upon as a service provided. The second section is giving information of the industry standard and guidelines for the mooring process of Suezmax tankers. Third section is concerning safety of ship and terminal crew, included herein is safety issues examples the author collected during the observations of mooring processes in the periods from 10th of April 2019 to 8th of May 2019 and in the period from 5th of June 2019 to 2nd of July 2019. Section four is covering the aspects of Suezmax tanker and terminal jetty interface while the fifth section is covering weather criteria concerning Suezmax tanker mooring process. Included in the fifth section is a description of existing mooring systems with its strengths and weaknesses. Chapter 2 is completed with section six covering emerging mooring technology.

2.1 Lean theory to be applied in Suezmax tanker mooring process.

The author will in this thesis focus on some of the principles found with in lean theory and put it into context with regards to mooring of Suezmax tankers. The thesis supervisor made the author aware of lean principles have been applied to a course subject at a master`s level student assignment when studying and evaluating loading and discharging of cars to a ropax ferry, see (Schøyen, 2018). Branch & Robarts (2014) argues for an innovative value-added approach is needed in the logistic chain to become flexible and responsive to a shipper`s need. A possible approach to achieve innovative value-added service is to apply lean principles adopted from the Toyota production of cars. Womack et. al (1990) found that lean production is a superior way for humans to make things. It provides better products in wider variety at lower cost. Equally important, it provides more challenging and fulfilling work for employees at every level, from the factory floors to headquarters. Womack et. al (1990) discovered that the employees agreed to be flexible in work assignment and active in promoting the interests of the company by initiating improvements rather than merely responding to problems. Lean principles for processes are focusing on the elimination of all types of waste. (Alukal, 2003). Simply focusing on waste reduction is not creating a lean thinking organization, it requires employees to question their processes and identify improvement possibilities, resulting in difficulties to separate blue- and white-collar work. (Dombrowski et. al. 2014).

Lean principles emphasize such things as teamwork, continuous training and learning and total productive maintenance among other. Lean implementation uses both incremental and breakthrough improvement approaches. (Alukal, 2003).

Rolfsen (2018) has through literature studies found four sets of how to understand lean. It can be understood as a way of organizing, ways to lead, as a set of principles and as a set of practical ways of performing tasks.

Lean as a set of principles identifies among others the following: Specify value perceived by the customer, identify the value stream generating the value, cut the waste, and finally improve the value stream through continuous improvement cycles. (Rolfsen, 2018). Alukal (2006) argues for lean is appropriate for reducing cost and time directly promoting productivity and it can also be useful for service organizations. Shah and Ward (2007) argues that lean is something you do, like a set of mutual supporting practises. These operational practises of lean can, if implemented and committed:

- Increase efficiency, effectiveness, and quality of processes.
- Lower operating costs.
- Improve customer satisfaction.
- Improve employee satisfaction and morale.
- Free up employees to work on other opportunities.

The improvement needs to create value for the customer, and human labour is a major part of the total value delivered to the customer and by centralization and well-thought-out uniform policies, it can create significant rewards (Ellram et. al. 2004). By applying a lean process, each step in the process needs to be identified for a possible improvement in that step, such a step must add value to the customer by meeting the criteria below:

- The customer must care about it or be affected by it.
- It must change the product or service (fit, form or function).
- It must be done right the first time.

Value is commonly understood by "*the perceived worth in terms of the economic, technical, service and social benefits received by a customer firm in exchange for the price paid for a product offering.*" (Anderson and Narus, 1991 p. 98). Lean is not something you do for money or profit, that is the by-product of lean processes. Lean is about respect for people, for quality of life, and the real asset of the company is the people, happy employees are functioning on a higher level, driving the cost down and increasing the quality of processes and products. (UpFlip, 2020, 3:50)

The Japanese word poka-yoke has the meaning that processes or products should be designed in such a way that physical errors cannot happen (Fujimoto, 1999). This principal is often used when it is important to deliver good quality of product or when in relation to safety, injury or harm to people and property.

Customers today are looking for a quick, reliable, and flexible service and offers the lowest price. (Song & Panayides, 2012).

2.2 Industry standard and guidelines for mooring of tankers.

The OCIMF (Oil Companies International Marine Forum) is an association of companies having an interest in shipping and terminalling of crude oil and other oil products. OCIMFs focus is to prevent harm to people and environment by promoting best practice in the design, construction and operations of tankers, and the interface with terminals. (OCIMF.org, 2020). OCIMF has developed a risk assessment tool concerning ship safety, and it has become known as Ship Inspection Report (SIRE) Programme. Tankers must pass several SIRE inspections a year, these inspections are become known as vetting inspections. The inspection is done aided with a document known as Vessel Inspection Questionnaire (VIQ) which make sure that the inspection is as uniform, user friendly and transparent as possible. This is unique in the marine oil and oil product transportation industry.

2.3 Safety of ship and terminal crew.

In this thesis the following definition, elaborated and based on the author`s experience will apply to the term safety: protected from or unlikely to cause harm or injury, to ship and terminal crew. To achieve an acceptable safety standard on board a Suezmax tanker, it is paramount that the company running the Suezmax tanker has a sound economy and thereby can work systematically and continuously with safety-related matters such as training of personnel, developing better technical standards and improving management routines. (Kristiansen, 2005).

During mooring and unmooring operations you stand a greater risk of injuring yourself or other ship and terminal crew than at any other time. (OCIMF, 2010). All involved in mooring operation need to be aware on how to identify risks associated with the use of the equipment, as well as human element considerations to address these risks. (OCIMF, 2018). (Crowl, 2007, p.2) uses The International Association of Oil and Gas Producers definition of human element as: "*the interaction of individuals with each other, with facilities and equipment and with management systems*." All accidents can be attributed to human element due to errors in design, construction, operation, or maintenance (Crowl, 2007). There are mainly two types of human element, and these elements can be divided between (1) human error and (2) non-compliance (violation). Human error is an unintentional unsafe behaviour such as failing to hear a signal, making a poor decision, while non-compliance is an intentional unsafe behaviour and may be a result of trying to save time or effort. (OCIMF, 2018).

Table 2. Common causes of mooring processes accidents.

Cause of accident	**Reason for accident**
Inadequate understanding	In Appendix 4, the Safety Alert dated April 2016 and Figure 3 in Chapter 1 for similar type of work being performed, and for further details of task at hand, see in Appendix 8 for the 6-month job of greasing and inspection of mooring lines. The author is considering this to the human failure account, since it is a challenging endeavour to classify it as either human error, or a non-compliance without performing a thorough investigation which is outside the scope of this thesis. The author is considering the Safety Alert dated August 2017 in Appendix 5 to an inadequate understanding of risks associated with task at hand, of what reason is unknown to the author and hence the author will not group it to either human error or a non-compliance. See Chapter 2.3, (OCIMF, 2018) the human element.
Unattended mooring lines	Appendix 1, the Safety Alert dated January 2014 is by the author considered to be classified as unattended mooring lines, even though it can be considered as inadequate understanding. To differ between human error or non-compliance is difficult and therefore the author considers this as a human failure.
Lack of mooring line/tail retirement	The Safety Alert dated June 2015 in Appendix 3 is by the author considered as lack of mooring line retirement and poor maintenance carried out. See Chapter 2.5.2. for more details of challenges with steel mooring lines. Figure 3 in Chapter 1 and in more details Figure 4 in Chapter 4 illustrates the maintenance process which can prolong or advance the mooring line retirement, including the human, machine and complexity involved with such tasks. For details of such tasks check Appendix 8, the 6-month job of greasing and inspection of mooring lines. The Safety Alert dated June 2015, Appendix 3, is showing the complexity of evaluating and grouping of the course of the accident, adding the challenge of human failures, to group it as

	either human error or a non-compliance makes it even a more challenging task.
Unbalanced mooring arrangement	The author will group the Appendix 2, Safety Alert dated March 2015 serious injury into the group of unbalanced mooring arrangement, it may even be attributed to the group line retirement, clearly illustrating the complexity involved in mooring processes. For further details of hazards associated with synthetic mooring lines check Chapter 2.5.3. See Chapter 4.7 on how alternative mooring system can facilitate this kind of Suezmax tanker movement along the berth.
Poor maintenance carried out	When poor maintenance is carried out it is a human failure, and it becomes visible to all parties involved when e.g., a mooring line is parting see example in Appendix 3, the Safety Alert dated June 2015. The challenging task is after the accident to find out and attribute the findings to either human error account or a non-compliance.
A lack of attention due to deteriorating weather and change in tidal condition or passing traffic.	The Safety Alert dated June 2015, Appendix 3, could even be attributed to this reason for accident. The increased challenge in grouping the incident to either this account or any of the other is clearly showing the casual network (Kristiansen, 2005, Chapter 2.3) leading to an incident or accident is complex.

Source: OCIMF SIRE VIQ7 Chapter 9 Mooring, table elaborated by the author.

The most common mooring winch drums in use are the split drum type which has one storage side and one tension side. During mooring of the Suezmax tanker, the mooring line need to be transferred from storage side to tension side, this involves manual handling by the ship`s crew which is difficult and requires care, vigilance, and sufficient ship crew. (OCIMF, 2010). The ship crew should not handle wires without leather gloves, this is to avoid wounds caused by “snags” (broken wire strands). These wounds may become infected leading to further medical complications. The utilization of loose-fitting gloves should be discouraged due to the increased risk of trapping between wires and other equipment. (OCIMF, 2005). To prevent such happening’s purpose designed steel hooks are to be used to minimize contact when handling mooring wires. (OCIMF, 2010).

When a line is loaded, it stretches. Energy is stored in the line in proportion to the load and the stretch. When the line breaks, this energy is suddenly released. The line recoils back to its original path but the path maybe changed when passing capstans, bollards or similar, striking anything in the vicinity with tremendous force, this is known as snap-back. (OCIMF, 2005). See in Table 2 under the unbalanced mooring and in the Appendix 2 for an example of such a type of accident.

Running of lines unchecked should not take place as ship crew may step into a coil or a loop of the rope and be caught resulting in serious injury. When the lines are lowered from the tanker, it could be from a significant height, resulting in heavy weight of line on the outboard side of the tanker causing the line to take charge. Trying to stop such a line by feet or hands may result in serious injuries. It is a good practise to have the tail end made fast onboard the tanker to avoid a complete loss. (OCIMF, 2005).

Investigations of some incidents and accidents on ships have identified that measures to protect the health and wellbeing of ship`s crew were not fully implemented, including failure to fully implement appropriate design or procedural measures and opportunities to enhance the operation through improvements in equipment design, controls or safety management procedures were not realised. (OCIMF, 2018). Kristiansen (2005) Accidents need to be seen as a process, where the activity in the maritime system is exposed to hazardous situations and therefore also to risks and undesirable incidents and accidents. An initiating event, together with contributing factors of operational, environmental, and technological aspects, constitutes the so-called casual network leading to an accident. (Kristiansen, 2005) The accidental event itself ignites an escalation process within the system under consideration e.g., a mooring operation, resulting a physical damage and release of energy which will expose humans, the activity, and the environment to various consequences (Kristiansen, 2005). Studies of accidents and incidents demonstrate that investing in the right design upfront can significantly enhance the health and wellbeing of personnel in the short term and save the cost of solving a problem later. (OCIMF, 2018)

Addressing human element appropriately is an important safety element, and by proper application, can improve operating effectiveness and reduce the risk of work-related injuries (Crowl, 2007). Maritime service quality can largely be equated with safety (Österman & Osvalder, 2012). There seem to be an understanding of why accidents happen involving the operator, technology, working conditions and organization and still the view in design and planning of operations seems to be narrowed, leading to whatever measures taken to reduce the risk of injuries or accidents, some residual risk will remain (Kristiansen, 2005).

Fundamental innovations have been driven by legislators e.g., the requirement for double hull tankers vs single hull. With innovation in shipping, it seems to be a stronger first-mover advantage. (Lorange, 2009).

2.4 Suezmax tanker and terminal jetty interface.

Harbours are where sea meets land and ships can enter to load or discharge cargo. In the harbour there need to be a jetty, wharf, or quay to facilitate a smooth transfer of cargoes, this is the interface between ships and harbours. To further smoothen the cargo transfer, the ships need to be safely moored alongside a jetty or similar harbour structure. The term “mooring” refers to the system for safely securing the ship to the berth structure, including the mooring hooks on the jetty and the onboard fixture to which the lines are restrained, whether that is a bollard or a mooring winch. (Thoresen, 2003, OCIMF 2018).

The author has in this thesis divided the mooring process into four main steps:

(1) maintenance of the ropes and gear

(2) preparations and planning of mooring operations

(3) the mooring/unmooring operation which include the shoreside/terminal, and

(4) the moored period when the ship is alongside loading or discharging cargo.

Ship moorings must withstand the most severe combination of wind, current, waves, swells, seiches, tides, surges from passing vessels and the change in trim, list, and draft changes due to cargo operations. The waves acting along the berth lines presents the most difficult force to calculate to find the resulting forces acting on the mooring system and those forces are the most common reason for broken mooring lines. (Thoresen, 2003).

To facilitate the safe securing of ships mooring lines to the port structure the port can have bollards or quick release hooks to put the mooring line eye onto. The bollards virtually require no maintenance except for maybe some rust removal and paint work, whereas the quick release hook need to be moved, lubricated and function tested. Thoresen (2003) argues that the maintenance of harbour structures will generally be proportional with the degree of the selected sophisticated solution.

2.5 Weather criteria for existing mooring system for suezmax tankers.

The discussion in the previous section implies that mooring lines are a critical component in the mooring process. The decision on the optimum mooring line should be made at the ship design stage following mooring analyses and discussions between the ship designers and operators. (OCIMF, 2018). Mooring pattern is the geometric arrangement of mooring lines between the tanker and the berth. The generic mooring pattern is to adapt to a multi-directional environmental condition. The OCIMF standard weather forces the mooring system is designed to satisfy: 60 knot wind from any direction simultaneously with, 3 knots current at 0 degrees or 180 degrees, or a 2 knots current at 10 degrees or 170 degrees, or 0.75

knots from the direction of maximum beam loading. These forces are known as the ship design MBL. All other parts of the mooring system are designed according to ship design MBL. However, these standard environmental criteria are higher compared to IACS (International Association of Classification Societies) EN tables updated December 2016, resulting for larger tankers a difference in mooring line strength and the number of mooring lines needed. (OCIMF, 2018)

2.5.1 General information regarding mooring lines.

Mooring line stiffness is important in the respect that low stiffness lines will stretch more than high stiffness line, directly influencing the area the ship may move within, when the lines are loaded. The effect of line length on load distribution must be accounted for. A line 60 m long will assume only about half the load of a 30 m parallel and adjacent line of the equal material type, construction, and diameter. Longer lines require less numbers of line tendering, than shorter lines. (OCIMF, 2018). The vertical angle the line forms with the pier, and the horizontal line forms with the parallel side of the ship is greatly influencing the effectiveness of the mooring. The larger a mooring line is, the less susceptible it will be to reduction of service life due to wear. HMSF mooring lines are considered a viable alternative to steel wire mooring ropes. (OCIMF, 2018).
The hazard of “snap – back” is common to all types of lines, but the more elastic lines are more dangerous due to the stretch, which will be released if the line breaks, striking anything in their path with a tremendous force. Synthetic lines normally break suddenly and without warning and even long wire lines under tension can stretch enough to snap back with considerable energy. High modulus synthetic lines have similar breaking characteristics to wire ropes. Snap back from these materials will be along the length of the line and not in a snaking manner as with wires. (Hensen, 2003, OCIMF 2010).

2.5.2 Steel wire mooring lines.

When a high MBL (Minimum Breaking Load) together with reasonable ease of handling is required, a steel wire line has traditionally been the obvious selection. This is due to the low elasticity, i.e., limited stretch, a strength/diameter ratio superior to most synthetic fibre lines and a smaller diameter making it suitable for use on storage reels that can be directly linked to the winch. (OCIMF, 2005) Wire lines can be supplied with fibre cores or steel wire cores. Fibre cores will give easier manual handling by ship crew. Mooring wire lines are usually galvanised to provide better resistance to corrosion. (OCIMF, 2005) Maintenance of the steel wire lines is very important, especially to grease or oil the steel wire lines at frequent intervals as rusting will reduce the strength of the wire in a very short time. Wire lines deteriorate gradually throughout their entire service life. (OCIMF, 2005). In service inspection methods for the detection and assessment of line degradation is by visual inspection by ship's crew or by electromagnetic inspections performed by an outside contractor. The ship`s crew can use visual inspection to look for any damage to the wire like broken strands in the wire, kink, birdcage or, flattening. The ship crew can also measure the line diameter and compare with the original diameter stated in the certificate. Areas of particular interest is the areas of abrasion such as the eye where the shackle connecting the soft tail line and the wire line, and the area on the mooring wire line normally passes the fairlead. (Hensen, 2003, OCIMF, 2005). Deterioration of the wire line can occur undetected at the bottom layers of the winch, especially when a wire line has seen some service and has been turned "end for end".

Steel wire lines, may under heavy load, give audible sings of pending failure or they may exhibit broken elements before completely parting. (OCIMF, 2005).

2.5.3 Synthetic fibre mooring lines.

Synthetic fibre mooring lines are normally made of HMSF (High Modulus Synthetic Fibre), nylon, polyester, polypropylene or a mixture of polyester and polypropylene. HMSF lines generally refers to lines made from high modulus fibres such as Aramid and High-modulus polyethylene (HMPE). These fibres are much stronger than conventional synthetic fibres such as nylon, polyester, and polypropylene. These conventional fibres are not strong enough to be used for tanker moorings, except as tail lines in the mooring system, to allow for some elasticity. (OCIMF, 2005). Aramid fibre typically has high strength and low stretch. The ropes do not float; however, they have good cut resistance but only fair ultraviolet and abrasion resistance. (OCIMF, 2005). HMSF lines have high strength per weight ratio, low stretch characteristics and good ultraviolet resistance. The HMSF lines do have very good fatigue (cuts, tension, abrasion and bending) resistance but limited temperature resistance. (OCIMF, 2005). Synthetic lines can be ordered with special finishes and coatings to deal with yarn-to-yarn friction and abrasion under operating conditions. In addition, the environmental and mechanical stresses can be reduced by application of external coatings, which will be applied to the line during production. (Hensen, 2003). HMSF lines are available in a wide range of fibre types, fibre grades, line constructions, fibre finishes and line coatings, which are used to enhance performance in the intended application. HMSF lines have many benefits due to their high strength to weight properties, diameter, and their relative ease of handling. (OCIMF, 2018) Now a day`s line manufacturers produce lines of unconventional construction to achieve a reduction in weight and/or elasticity, and an increase in strength. (OCIMF, 2005). During use and storage at ships it is important to check the entire area where the lines run to ensure that there are no chafing surfaces, as this will quickly damage to line and render it below acceptable standards. (OCIMF, 2010). The major danger with synthetic lines is the sudden release of the energy stored in the stretched synthetic line when it breaks, known as snapback. When synthetic lines break, it normally happens suddenly and without warning. (OCIMF, 2005)

Tugs assisting tankers during mooring operations, both while berthing and unberthing, connect to the tanker with the usage of synthetic fibre lines. The fibre lines provide the strength required to meet the increased bollard pull required by the tugs, whereas steel wires of equal strength would be increasingly difficult to handle, not only by the tug`s crew but also by the ship crew onboard the Suezmax tanker. (Hensen, 2003)

Table 3. Overview of mooring lines typical in use on Suezmax tankers.

Type of line	Diameter (mm)	Mass (kgs/100m)	MBL (tons)
Wire	40	669	103
HMPE	40	71	114
Aramid	40	132	122

Source: (Hensen, 2003, OCIMF 2010, www.katradis.com June 2019), complied by author 2019.

2.5.4 Mooring line tails in use on Suezmax tankers.

Nylon made lines are often used as tails for mooring ropes and act like shock absorbers. These tails effectively cushion the mooring lines they are attached to and saves them from progressive damage. The tails are usually about 11 – 12 meters in length fitted to the shore end of mooring line, and its eye will be protected from bollard and quick release hooks chafe by means of canvas parcelling. (Danton, 1996).

2.6 Emerging mooring technology.

Emerging mooring technologies are mooring systems that exist but are not currently widely used, e.g., vacuum, and magnetic mooring systems or it could be mooring technologies that may not yet exist but could be developed in the future, to improve the safety and efficiency of mooring ship to a berth. (OCIMF, 2018). An automatic mooring system

(Thoresen, 2014) is using the vacuum principle to moor ships to berth structures within approximately 30 seconds. A single operator with a remote-control system can moor any kind of ships if the ship has enough flat parallel body for the vacuum pads to attach to (Thoresen, 2014). New or alternative technologies for tanker mooring systems must according to OCIMF MEG4 (Mooring Equipment Guidelines 4, 2018) be at least as good as the existing technology at delivering the following:

- The safety of ship and terminal crew.
- Offer suitable margins of safety in case of failure of the mooring system.
- Operational effectiveness and integrity.
- Compliance with regulations, standards and recommended industry guidance and best practice.

3 Method

This chapter gives an overview of the research methods used in this thesis. The author will start with the choice of research strategy, based on a discussion on the different methodological aspects available in academic research. The author argues for the chosen design. This is followed by a brief description of the data collection method, before a discussion of the sampling and a description of the data analysis process. This, in turn, is followed by a discussion on the implications of reliability, validity, and ethical considerations. The method chapter is concluded with some considerations of limitations applied to this thesis.

3.1 Research Strategy.

Research strategy is the common direction of a research, and when the research strategy is chosen it gives a path to follow. Collected data can test theories, which is a deductive approach or theories can emerge from the collected data which is an inductive approach. There is not a clear-cut division between the two strategies "*as deduction entails an element of induction, the inductive process is likely to entail a degree of deduction*." (Bryman, 2016, p.22) Quantitative research is often associated with a deductive research strategy, whereas an inductive strategy of linking data and theory is typically associated with qualitative research. (Bryman, 2016). These two distinct paths differ in the way data is collected and analysed. Bryman & Bell (2015) distinct the quantitative strategy from the qualitative strategy by that the former is focused on obtaining large quantities of data, enabling generalizability, which is one of its main features, whereas the latter focuses on obtaining rich, high quality data by examining the samples at a deeper level to get a more thorough understanding of complex issues. A common way to differentiate quantitative research from qualitative research is to distinguish between numeric data and non-numeric data such as words, images, etc (Saunders et. al., 2016). The author can use one or several techniques for collecting data, but the techniques need to be coherent and with connected steps to answer the research question (Saunders, et.al, 2016).

The strategy used in this thesis is the qualitative, due to the goal of gaining in-depth knowledge in the context of mooring processes of Suezmax tankers. The mooring process is subjective and complex for all ship and terminal crew involved. The respondents` experiences and beliefs will be expressed in phrases, and the author will be interpreting the collected data after close interaction with the respondents. The emphasis of this thesis is based on the respondents` opinions in their natural settings of mooring processes of Suezmax tankers. Respondents have different meanings attached to the mooring process and interactions playing out among individuals within the mooring process leading the author towards the qualitative approach as the most suitable for this thesis. This way of performing research will require a highly structured methodology, aiding in the need to be replicated and it is important to ensure reliability of the research (Saunders et. al., 2016). Saunders et. al. (2016) further claims deductive approach need to be operationalised in a way that enables facts to be measured, the research problem to be reduced to the simplest possible elements, reductionism, and to be generalized. Sample needs to be done carefully and of enough size to have a good generalization.

3.2 Research Design.

Frankfort-Nachmias & Nachmias, DeWaard (2015, p.99) claim that the research design is "*…the program that guides the investigator in the process of collecting, analysing and interpreting observations.*" Studying the literature concerning research design reveals that there are several different designs to choose from. Taking a closer look at the characteristics of each design let us to some extent divide them into five major groups. Bryman & Bell (2015) named these groups: experimental design, cross sectional design, longitudinal design, comparative design, and case study design.

The experimental design is rarely used in social research due to the difficulties of manipulating variables when studying behaviours of humans (Bryman, 2016). A survey is an example of a cross sectional design, where e.g., questionaries are used to collect data, preferably large data, in a short period, to reach quantifiable information that can explain variations. If this study includes at least two measures with the same samples performed at different time, the design is called longitudinal with the purpose to identify and describe patterns of change (Bryman, 2016). A case study design is an empirical enquiry that investigates a contemporary phenomenon in depth and within its real-life context (Yin, 2014). The case study design is suitable when the aim is to collect data from natural settings, hence a case study is an appropriate design when the research is answering a “why” or “how” question and the collected data are from their natural setting (Yin, 2014). Bryman (2016) argues for a case study is associated with a qualitative strategy. This kind of design requires the case to be defined, see chapter 3.3.

The research question in this thesis is two folded. The first question is: What is the mooring process of Suezmax tankers? and the second research question is: How can the mooring process of Suezmax tankers be improved? The “how” question and the nature of the research topic, the mooring process, which involve ship and terminal crew, it seems to be the choice of a case study design to be most suitable in this thesis. When the case study design has been chosen, it is required to evaluate if this is just a single case or of multiple cases. This thesis is only referring to one terminal in the southern part of Norway, and with only one type of tankers, the Suezmax tankers, which are seen as the unit of interest, so the design will be a single case, with holistic design.

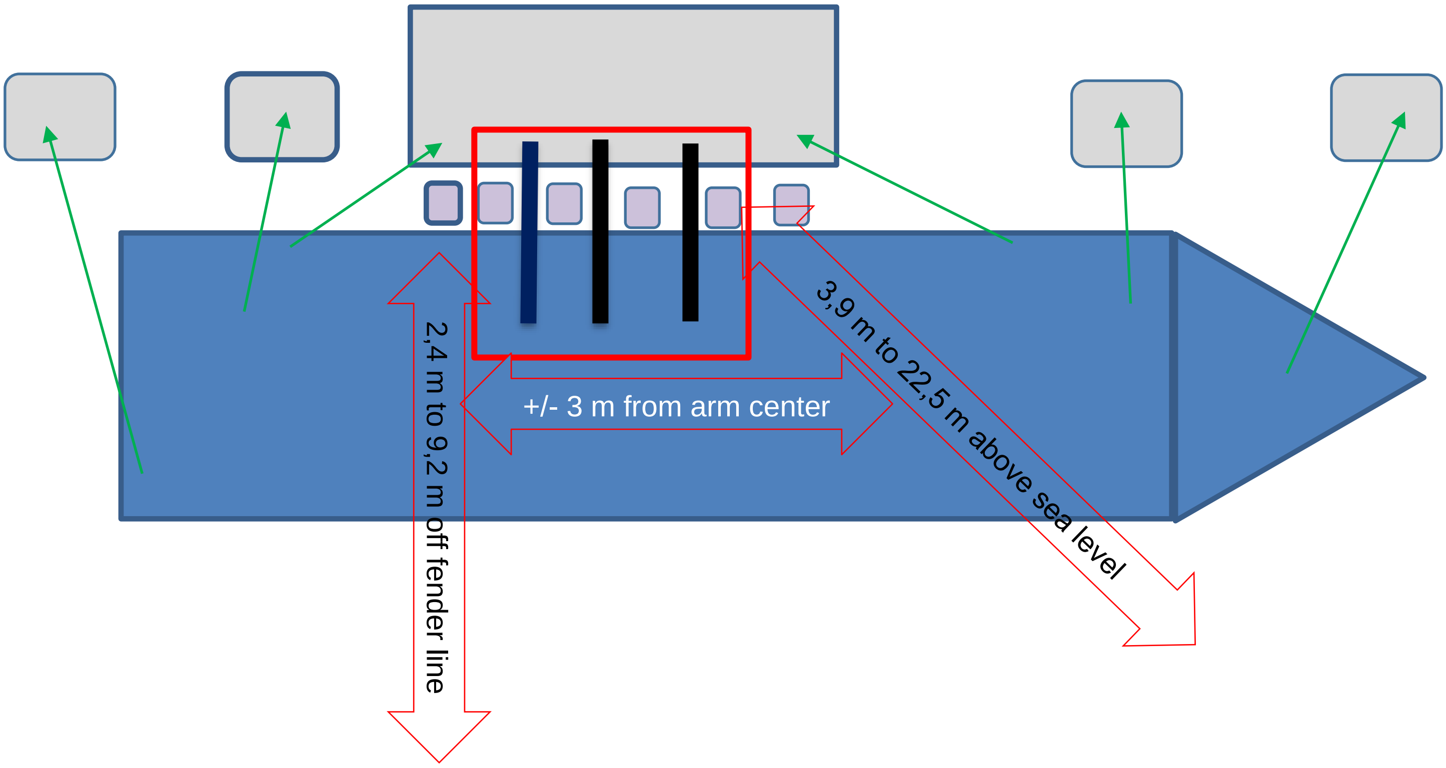
“*…the case study`s unique strength is its ability to deal with a full variety of evidence- documents, artifacts, interviews, and observations -.”* (Yin, 2014, p. 12).

3.3 Case description of Suezmax mooring process.

The focus in this thesis is at the mooring process between the terminal and the Suezmax tanker. The mooring process is complex and involves risks to both ship and terminal crew and to property, and to counteract those risks OCIMF has developed some tools to enhance safe performance. As a starting point for this case study the author has given below a brief resume of a Suezmax tanker calling a terminal after departure from a load port around the North Sea basin. The terminal chosen as a reference for this thesis is a well-established terminal. It has been in service for some decades, and it is an import and export terminal, importing crude oil and exporting petroleum products. The author has through his former work occupancy called this terminal on several occasion for discharging crude oil. From a port within the North Sea basin it is between 24 – 48 hours sea voyage before calling the pilot pick up point. Time consumed for pilotage is about 1,5 hours to reach the sheltered area and then roughly 1,5 hours for manoeuvring and mooring operation. The time spent on the mooring operation is the core issue in this thesis. Time spent for the mooring operation is collected in Table 10. This time consumption represents possible value added in this crude oil supply chain by saving time and thus reduce the total time spent. On the other hand, failures or incidents may arise, delaying the mooring process due to unforeseen or unaccounted for happenings onboard the Suezmax tanker, see Table 2 for examples of such happenings, or the terminal, adding time delay to the crude oil supply chain, and the lost time can be considered waste. Time consumed from finished mooring to gauging of cargo tanks and completion of cargo calculation and commencement of discharge amounts to about 3 hours, and normally the ship is empty after 18 to 20 hours discharging, including cowing (crude oil washing) and stripping. Departure is taking place roughly 2 hours later, after the ROB (Remaining Onboard quantity) measurement and calculation is completed. After pilot is onboard it takes roughly 0,5 hours to cast off and another 1,5 hours to the pilot drop off point. To be back at the North Sea basin is about 24 – 48 hours, depending on where the ship is scheduled to load next cargo.

When a tanker is calling the terminal, it is customary that the berth operators supply marine loading arms to be connected to the tankers manifolds for safely discharging or loading oil and oil products. The marine loading arms have an envelope in which they can move safely (OCIMF, 2005). Due to tankers` huge difference in draft from loaded condition to ballast condition or vice versa, and trim change during the loading and discharging operation, these arms are required to have a huge range flexibility in the vertical direction. In the ship longitudinal direction and transverse direction will the arms need to be somewhat flexible as the tanker rarely or seldom are static in the water. The tanker is under influence of forces from wind, current, waves and swell. These forces may under certain conditions be extreme, which will demand a lot of the mooring system to keep the tanker in correct position. The primary purpose of the mooring system is to keep the tanker within the acceptable limits of the marine loading arms. To accommodate such requirements, it is typical to use steel wires with soft tails, or not so common, High Modulus Synthetic Fiber (HMSF) ropes with soft tails which are connected to quick release hooks on the terminal. The first steel wire rope produced was in the early/mid 1800, while fibre ropes have existed for over 5000 years. (Danton, 1996). The only widely used automated mooring system has been in service for 20 years. (Cavotec.com, 2020). In the crude oil tanker trade, there are not installed any automated mooring systems.

Figure 2. Illustration of typical mooring layout of Suezmax tankers moored to a terminal handling crude oil.



Grey box = Terminal mooring hook and pulleys

Green arrow = Tanker mooring lines

Purple box = Terminal fenders

Blue box and triangle = Tanker

Black lines = Steel arms for transferring of crude oil or petroleum products

Red square = Envelop for typical maximum permissible steel arm movement

Source: Slagen Refinery Harbour Procedures, (2011). This booklet is handed out to all tankers calling the terminal, the author was permitted by the Suezmax tanker where the observations was done to get a copy of the booklet. Figure 7.1 Thoresen, (2014 p. 176) adjusted by the author Mar 2021.

The selected terminal is chosen due to it has frequent ships calls from tankers arriving from all over the world, in addition to some tankers calling at regular basis. The author believe it is an advantage that the tankers calling are of various physical seizes, requiring the terminal to be versatile and flexible to accommodate all kinds of physical sizes of tankers, it enhances the possibilities of different aspects of the mooring process. Yin, (2015, p. 52) argues for common case study that "*the objective is to capture the circumstances and conditions of an everyday situation*" In addition, the terminal is located close to the authors home and it is chosen of convenience such as short traveling distance to keep the costs in monetary terms and time at a minimum. The ease of accessing data due to the authors former work relations and experience with this terminal was an important factor when the case was decided.

3.4 Data collection methods applied in this thesis.

When the author has chosen the design to be used in the research it is necessary to decide how the data will be collected. In a case study the data can be collected from many sources spending from documentation, archival records, interviews, direct observations and other. (Yin. 2014.) The data collection methods are presented below.

3.4.1 Documents collected during the work with this thesis.

"*Because of their overall value, documents play an explicit role in any data collection in doing case study research*." (Yin. 2014 p. 107) In this thesis, documents published by OCIMF and oil terminal booklets received when the Suezmax tanker is calling the selected oil terminal played a vital role in establishment of the frame of the research. In addition, the author used the resources available at the USN library combined with knowledge gained in subjects studied at the master in maritime management study at USN to further set the frame and focus perspective of this thesis. Other documents such as work descriptions and mooring safety related issues became available when granted access to look into the Suezmax tanker PMS (Planned Maintenance System) and QA (Quality Assurance system). Documents granted permission to use in this thesis are displayed in the Appendices chapter, these are reports of actual incidents and maintenance tasks related to the mooring process.

3.4.2 Observations performed onboard a Suezmax tanker.

In this research the author has done observations of the maintenance, preparation, and mooring processes done with steel mooring lines in the periods from 10th of April 2019 to 8th of May 2019 and in the period from 5th of June 2019 to 2nd of July 2019 when at work on board a Suezmax tanker, serving in a senior officer position. Philosopher Alfred North Whitehead apparently once have said: "*Familiar things happen, and mankind does not bother about them. It requires a very unusual mind to undertake the analysis of the obvious*." To do observations the researcher has to assume membership roles in the community they want to study. (Denzin & Lincoln, 2011). The researcher brings their own "glasses" (i.e. way of thinking, gender, social class, etc.) in this thesis, the author is in the occupation as a chief officer, see Table 5 for details related to responsibilities in the mooring process and maintenance, into the observation process and obviously this will influence the ship crew observed during the processes related to mooring operations.

Wadel et. al., (2014) mentions that observations can be practically difficult due to issues of being granted attendance to observe, and once observing, the researcher is within the activity ongoing and may take active part, losing sight of the researcher task, however by time the researcher`s influence in the activity will diminish, due to the fact that people tend to forget the study and continue the normal way. Saunders et.al (2016) presents observations as a data collection tool to be useful for researchers working within their own organisation. Denzin & Lincoln, (2011) argues that the effect of the observer`s presence can never be erased. On the contrary Denzin & Lincoln (2011) argue that when the researcher is acquainted to the studied activity, it is possible for the researcher to move into focused observation mode and when in this mode the researcher can with some confidence sort the relevant from the irrelevant and this is particularly useful on well-defined types of group activities, like the maintenance and mooring process with mooring lines. Denzin & Lincoln (2011) further say interviewing is required because researchers cannot rely on their own intuition to make such discernments based solely on the focused observations. During the observations, in the period from 10th of April 2019 to 8th of May 2019 and in the period from 5th of June 2019 to 2nd of July 2019 when at work on board a Suezmax tanker the author made inquiries to the bosun, see Table 5, to clarify what they are doing, why they are doing like this and time usage for each task when working with mooring related equipment. The author assessed that a more structured interview with the bosun was not required, the collected data was considered good.

3.4.3 Interviews with purposive sampled participants.

"*The development of good interview questions requires creativity and insight and depends fundamentally on your understanding of the context of the research.*" (Maxwell, 2013, p. 101) "*One of the most important sources of case study information is the interview.*" (Yin, 2009, p. 106). An interview is a conversation that has a structure and a purpose, and the researcher defines and controls the interview situation with the purpose of obtaining thoroughly tested knowledge (Brinkman & Kvale, 2015). Yin (2009) argues that you can ask key respondents about the facts of a matter as well as their opinions about events. Purposive sampling, Bryman & Bell (2015) was applied as a fixed sampling strategy to find key respondents. To be targeted as a potential respondent in this research the criteria to be met is either to have a hands-on experience and tacit knowledge with the processes to be studied or profound knowledge of emerging mooring technology in addition to organize marine transportation.

The author set out to do a pilot interview with a head of a marine transportation organizer company. The rationale for a pilot interview was to map real life issues and identify opportunities to focus and give a direction too this thesis. It was a nondirective interview (Nachmias, et.al., 2015) where the author gave little direction to the respondent to have the respondent elaborate on experience and topics that seem significant to the respondent. During the interview, the author used probing (Nachmias, et.al., 2015) to promote discussions for enhancing more information collection. During the interview, the author took notes by pen and paper to write a summary after the interview, by doing so the author mapped possible research opportunities based on the information the respondent provided. By the information extracted it became evident a lot of metrics were measured such as pumping time, transit time, vetting etc. see Chapter 4.4 for the summary of the pilot interview.

Semi-structured interviews were used for the remaining interviews as a data collection tool in this research since the research intends to gain consistent understanding of and different perspectives of the Suezmax tanker mooring process in general, and further to identify resources required and issues related to mooring/unmooring operations, and then especially the safety related issues. The semi-structured interview has a list of questions divided into themes and the actual interview process is flexible, and the process is dependent on how interviewees understand the concept and how willing they are to provide data about it and contribute to knowledge creation (Bryman & Bell, 2015).

Table 4 Overview of interview informants participating in this thesis.

Informant	Respondent information
Pilot interview informant: Head of marine transportation organizer	Former sailor and now heading chartering department. The informant has more than 40 years' experience in the maritime domain in various work positions.
2nd interview informant: Terminal crew	A fellow student at the master in maritime management program who is working with mooring of all kinds of tankers at a terminal. The respondent is very often the boat driver of the mooring line handling boat during mooring operations. The respondent has 5 years of experience with mooring operation of various tankers, before this job the

	respondent was working on a shrimp trawler.
3rd interview informant: Pilot	A special trained pilot for docking of Suezmax tankers to the terminal. The respondent has more than 15 years of experience as a pilot. The respondent pilot is the main supervisor for the pilots undergoing training in docking of the Suezmax tankers to the terminal. The pilot and the author are colleagues.
4th interview informant: Sales representative for automated mooring	Sales representative for a company suppling automated mooring system.

Source: The authors purposive sampling strategy.

Two of the interviewees where known to the author from before due to former and present working relation. This can influence the participants` willingness to participate in the research and the type of the data collected. The 2nd interview was with a respondent working on the terminal side of the joint mooring process, often manoeuvring the line handling boat. This interview was done 4th of September 2020, the author reading out the questions from the interview guide, while the respondent`s answers where audio recorded with the authors cell phone. The same afternoon the interview was transcribed to the author`s laptop. The results are presented in the result part.

The third respondent received the interview questions by email from the author`s email address the 15th of September 2020. No oral interview was performed, but the participant emailed the authors his written response to the interview questions on the 21st of September 2020, emphasising on his impressions of the most relevant parts in the mooring process. This respondent is a specially trained marine pilot for manoeuvring, mooring and unmooring operations of suezmax tankers to an oil terminal. This respondent is stationed on the bridge of the tanker coordinating the whole mooring and unmooring process. The findings are presented in the result part.

Due to time constraint and travel restrictions relating to covid -19, the fourth interview was done through Teams platform as a video interview at 6th of October 2020 starting at 13:00 ending 13:35. The author audio recorded the interview with his cell phone and transcribed to the authors laptop. The results are presented in Chapter 4. The fourth respondent is a sales representative from a leading company suppling automated moorings. This respondent is representing a different approach to the mooring and unmooring process than the other respondents.

The transcription of the interviews is done solely by the author. The author audio recorded the interviews with his mobile phone and transcribed each interview into a separate word file at the authors laptop. All data collected are stored on the authors laptop in designated file folder and will be erased once the thesis is handed in and completed.

3.5 Ethical considerations.

Important aspects within research are the trust, confidentiality, respect and reciprocity between the researcher and the participants. Our behaviours at the time of inquiry will influence on the communication and might alter respondents wish to participate and to speak freely. Courtesy is a starting point for ethical good research (Tjora, 2017).

In this research the author has not collected any names nor other personal information, hence this research is not notified to NSD. All participants are informed and has given their consent to participate. Data stored on the authors mobile phone and laptop will be erased after the thesis is completed.

3.6 Data analysis.

Qualitative analysis is consisting of three concurrent flows of activity: data reduction, data display and conclusion drawing. (Miles & Huberman, 1994). Qualitative research focus on words based on observations, interviews, or documents, and are not immediately ready for analysis, hence the first step in the analysis is to write clear texts from the field observation notes and audio recorded interviews. (Miles & Huberman, 1994). The authors approach in the data analysis was to write clear texts from observations and from the audio recorded interviews into a word file. The next step was to look for recurring subjects in the transcribed text. Through the data reduction process the author was looking for core meanings, to find key element and put them to display in a Tables 9 and 10. The meanings emerging from the data must be tested for their plausibility, that is their validity. (Miles & Huberman, 1994). The table is presented in Chapter 4 Results and is later brought up in Chapter 5 Discussions, divided according to the themes to promote a good discussion. During the process, the author worked back and forth between the data and the analysis.

3.7 Reliability and validity.

Regardless of research design, all research should meet criteria aiming to evaluate the research. The criterion concerning repeatability and consistency of the result of the research is reliability, whereas validity concern the integrity of the conclusions drawn from the research.

Reliability can be divided into external and internal reliability where the external reliability is concerning the replicability of a study. Bryman (2016) argues that it is difficult in qualitative research because it is impossible to redo a social setting and the circumstances of an initial study and due to the complexity of the phenomena being studied, but different strategies can be used to approach the requirements for external reliability. In this thesis all the data collection steps has been presented. Regarding internal reliability Bryman (2016) claims that is important if there are more than one observer or researcher that the participants are uniform in what they see and hear, in this thesis this is not important as the work is being performed by only one researcher.

Validity is separated between external and internal validity, where the external validity is to which degree findings can be generalized across social settings and internal validity concern the correspondence between observations the researcher made and the theoretical idea they develop. For qualitative research, the external validity is challenging due to their tendency to use case studies and small samples, Bryman (2016) which is applicable for this thesis. On the contrary, internal validity tends to be a strength of qualitative research due to the prolonged participation in groups aiding the researcher to develop congruence between observations and theoretical concepts, Bryman (2016), for this thesis it is important to point out that the author has been working in a senior position on board a few different Suezmax tankers for 12 years, actively participating in the mooring process being studied. During the 12 years of service the author has spent several hours doing various visual inspections of the Suezmax tanker`s mooring equipment which has led to the author`s experience and profound knowledge on this subject, but to further explore the process, the author needed to gain insight of other industry professionals, to control any biases the author should possess.

During this research, the author has changed work occupation from a senior officer onboard Suezmax tankers to become a marine pilot, subsequently this has resulted in significantly prolonged work with the thesis. However, the working occupations have aided in the data collection process, where it has facilitated contact with informants who wanted to participate.

The author has been working for years with the crew being observed in this thesis, so the author`s presences in the activities studied is not something unusual to them, nor the author, but note that the author is their closest superior officer, who of course will be of some importance for the results collect through observations as manipulation can occur. In addition, triangulation can be applied to further support the validity of the paper.

3.8 Triangulation of data.

Triangulation is loosely derived from navigation and survey profession. One line on the map only tells you that you are somewhere along that line, but when you have two lines, an exact position is obtained. One way of triangulation is to check and compare collected data from one source with data collected from other sources, this is also termed respondent validation. "*Data-source triangulation involves the comparison of data relating to the same phenomenon but deriving from different phases of the field work.*" (Hammersley and Atkinson 2007, p. 183). This approach provides a validity check and adds a depth to the research. (Hammersley & Atkinson, 2007). The author, based on own experience, compared the collected data from interviews, documents and observations with own experience and found the data to be credible.

3.9 Limitations of the thesis.

The thesis is limited to the Suezmax tanker mooring process, see Chapter 2.5 for details of each step. In the thesis, Chapter 2.5 the point 2: preparations and planning of mooring operation and point 4: the moored period, when the ship is alongside loading or discharging cargo, are given less attention due that point two is to follow established routines and procedures whereas point 4 is normally for prolonged periods of monitoring and adjusting of the mooring lines performed by the ship crew during hourly visually inspection of the mooring system. These two points are by the author considered less hazardous then the two remaining points which are given most of the attention in the thesis. The process of unmooring is let out of the thesis to limit the thesis, but an example of an unmooring operation incident is included in Appendix 1, the Safety Alert dated January 2014, to show that no part of mooring process is risk free.

The use of harbour tugs and escort tugs is not included in the thesis, even they are needed for pushing or pulling the Suezmax tankers to the berth. The tugs are requiring the assistance from the Suezmax tanker crew to make fast the tug line, and to cast off when the mooring process is completed, which both are hazardous operations. In addition, tugs are communicating via VHF (Very High Frequency) radio with the pilot, which could influence or disturb the mooring process, but nevertheless, the tug and usage of tug is by the author considered outside the scope of this thesis and therefore not presented. The anchoring and heaving anchor operations is by the author also considered outside the scope of this thesis.

The oil market is volatile and huge fluctuations in oil price has been experienced throughout history, resulting in congestions in port or in contango, but in the thesis` context the author is considering it negligible since the mooring system is decided upon the design phase prior to the building phase, and the expected lifetime of Suezmax tanker is 20 years, the mooring system is not something that is changed overnight.

The author noticed during the period from 10th of April 2019 to 8th of May 2019 and in the period from 5th of June 2019 to 2nd of July 2019onboard the Suezmax tanker the ship crew employed are from Norway, Sweden, Poland and the Philippines, this mixture of ship crew could lead to possible difficulties or advantages in mooring operations due to cultural differences, but cultural differences are not part of the thesis. Human failures are used as a common explanation in the thesis and the author is not differentiating between human error and non-compliance, because a full investigation is required to conclude what type of human failure is the reason behind the accident, incident or fatality and this investigation is considered by the author to be outside the scope of this thesis.

External factors such as commercial monetary aspects are left out. This includes, but are not limited, to operational decisions made by the terminal who set up the ship rotation at the jetty, which may lead to demurrage claims or lengthy anchorage stay. Requests from charterer to speed up or slow down which has a direct effect on fuel consumption and exhaust emissions are not considered in this thesis. In this thesis it is not made any efforts to identify any customers due to difficulties in mapping of who is the customer, it can be someone within the organization or it can be someone outside the organization.

The pilot is included in the thesis due to the role the pilot is playing in positioning the vessel alongside the jetty. The pilot is also a crucial point of communication during the mooring process and can be seen as employed by, and providing service to, the Suezmax tanker, in addition, most countries it is compulsory to employ a pilot when calling port.

In this thesis the focus has been on the ship and terminal crew who actively participates in the mooring processes and/or have first-hand responsibility, experience, and knowledge of mooring processes.

4 Results

This chapter presents the findings from observations made during the time onboard a Suezmax tanker, and from the four interviews completed. The data are presented within sub-chapters divided into steel mooring wire line maintenance, steel mooring wire line usage, HMSF mooring line usage and automated mooring process which can be seen as an emerging mooring technology. The chapter is concluded with summary tables covering strength and weaknesses of each mooring system, the benefit of HMSF mooring line versus steel mooring line and a table to sum up potential time saving compared to steel mooring wire line.

Below is an extract of a typical Suezmax tanker crew list, in the thesis the author has not considered the different tasks the ship crew are given through the hierarchical system established onboard, for the purpose of the thesis all ship crew are regarded as equal.

Table 5. Suezmax tanker ship crew list with designated mooring duties.

Ship crew position on board	**Location of duty when mooring**	**Duty during mooring operation**	**Duty during maintenance**
Captain	Manoeuvring bridge wing, reference to Figure 5 and 6 for a situational view.	Manoeuvring the tanker	Overall responsible
Chief Officer	Manoeuvring bridge wing, reference to Figure 5 and 6 for a situational view.	Communication via UHF (Ultra High Frequency) radio with in the Suezmax tanker, log keeping. Prepare and arrange meeting with the crew to participate in the mooring process upfront of arrival, checking JHA (Job Hazard Analysis) and what can be expected.	Purchasing of spares and consumables, follow up maintenance tasks, promote safe working practices according to QA system
2nd Officer	Forecastle	In charge of mooring operation at the forecastle area, communicating via hand signalling with terminal crew in the line handling boat and at the jetty in addition to Suezmax tanker crew stationed at the forecastle area. Communication to manoeuvring bridge is via UHF radio.	Not Applicable
3rd Officer	Poop deck	In charge of mooring operation at the poop deck area, communicating via hand signalling with terminal crew in the line handling boat and at the jetty in addition to Suezmax tanker crew stationed at the poop deck area. Communication to manoeuvring bridge is via UHF radio	Not Applicable
Chief Engineer	Engine Control Room (ECR)	Start and stop of machinery as communicated from the manoeuvring bridge	Head of technical issues, supporting chief officer with additional ship crew if required and know how experience when needed.
1st Assistant Engineer	On/Off Duty in ECR	Assist Chief Engineer	Not Applicable
2nd Assistant Engineer	On/Off Duty in ECR	Assist Chief Engineer	Not Applicable
Electrician	Engine Control Room	Assist Chief Engineer	Not Applicable
Bosun	Forecastle	Mooring winch operator at the forecastle area	Delegating tasks and ship crew assigned to each task to meet the demand for

			experience and safe working practises. Supply tools and consumables needed to execute the tasks at hand.
Pumpman	Poop deck	Pulling/handling of mooring lines	Executing tasks delegated
Able-bodied seaman 1	Forecastle On/Off Duty	Pulling/handling of mooring lines	Executing tasks delegated
Able-bodied seaman 2	Forecastle On/Off Duty	Pulling/handling of mooring lines	Executing tasks delegated
Able-bodied seaman 3	Poop deck On/Off Duty	Pulling/handling of mooring lines	Executing tasks delegated
Ordinary Seaman	Poop deck On/Off Duty	Pulling/handling of mooring lines	Executing tasks delegated
Fitter	Poop deck	Mooring winch operator at the poop deck area	Not Applicable
Motorman 1	Forecastle On/Off Duty	Pulling/handling of mooring lines	Not Applicable
Motorman 2	Poop deck On/Off Duty	Pulling/handling of mooring lines	Not Applicable
Oiler 1	On/Off Duty in Engine room	Assist Chief Engineer	Not Applicable
Oiler 2	On/Off Duty in Engine room	Assist Chief Engineer	Not Applicable
Chief Cook	Not Applicable	Not Applicable	Not Applicable
Messman 1	Not Applicable	Not Applicable	Not Applicable
Messman 2	Not Applicable	Not Applicable	Not Applicable

Source: Mooring duty list and crew list displayed onboard the Suezmax tanker, combined and adjusted by the author.

The pilot is stationed on the manoeuvring bridge together with the captain and chief officer. From this position the pilot advice the captain in manoeuvring the Suezmax tanker to the jetty and communicates via VHF with supporting tugs and the terminal crew advising the correct position along the jetty. The pilot is communicating via VHF to the mooring line boats.

4.1 Suezmax tanker requirements of maintenance of mooring equipment with steel mooring line.

All required maintenance is carried out as outlined in the table below, see appendix for full details of maintenance requirements. The table is giving an overview of details concerning maintenance requirements. The maintenance schedule is important to follow to avoid any malfunction or breakdown of any mooring equipment during usage, which in turn can cause significant delays due to abortion of cargo operation or it may even cause damage to property or ship and terminal crew.

The author compiled the table below from data collected in the PMS (Planned Maintenance System) onboard the Suezmax tanker where the observations took place. The data was collected in the period 10th of April 2019 to 8th of May 2019 and in the period from 5th of June 2019 to 2nd of July 2019 . Only the tasks related to mooring process is compiled.

The times given are based upon discussion with the bosun (leader of the deck operators) onboard in the period from 10th of April 2019 to 8th of May 2019 and in the period from 5th of June 2019 to 2nd of July 2019.

Table 6. Summary of Suezmax tanker mooring equipment maintenance tasks and ship crew hours needed to complete the mooring equipment maintenance tasks.

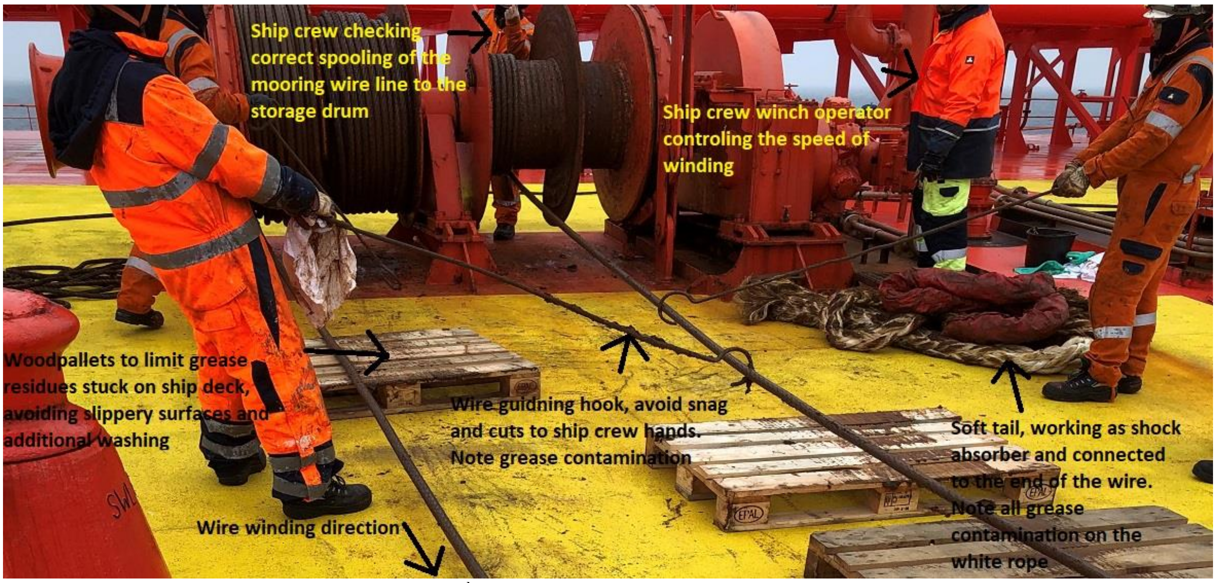
Maintenance task	**Frequency of task**	**Number of ship crew used.** (Table 5 provides an overview of which ship crew are used to these tasks.)	**Time used in hours**	**Ship crew hours**
Inspection and lubrication (All lines)	Once a month	3	10	30
Inspection (All lines)	Every 3rd month	3	10	30
Inspection and lubrication (All lines)	Half yearly	3	10	30
Break testing (All lines)	Once a year	4	20	80
Replace mooring tail (16 tails)	Every 18th month	3	1 hour/tail	48
Turn wire end for end (each wire line)	Every 30th month	6	4.5	27
Install new wire (remove old wire and store for disposal. Greasing new wire and clean	When wire is below acceptable standard or is broken	4	10	40

the area when completed.)				

Source: Compiled by the author from Suezmax tanker PMS system and discussion with the bosun, see Chapter 3.4.2 for more details.

The below photograph is from a maintenance situation on the forward breast lines. The ship crew is performing the task of turning the wire end for end, an every 30^{th} month task, check in appendix chapter for full details of the task at hand and Table 6 for details of hours consumed for such a task. The mooring winch at the photograph is of the split type, meaning they have a storage side and a tension side; hence the photograph is showing the mooring system for two steel mooring lines. The steel mooring line is transferred from tension drum on one winch which are running freely with only one ship crew (partly hidden, upper left corner) controlling the brake, to the storage side of the second winch which is in this case hydraulic driven and engaged, the winch operator, normally the bosun, see Table 5 for more details of this ship crew position is marked at the photograph. Table 5 is giving information of which other ship crew is also participating in maintenance routines. At the photograph there are six ship crew participating, note; it is only possible to see the shoe tip of the sixth ship crew member at the bottom right corner. At the photograph there are some comments to further explain the situation.

Figure 4. Ship crew performing maintenance of forward breast winch and mooring line.



Source: Photograph taken by the author at sea 6th of June 2019, view from main deck forward portside towards the forward breast winch and starboard side railing can be seen in the vicinity. Arrows and text are put in by the author to point to important aspects, and to increase the understanding of the ongoing maintenance of steel mooring wire line, the reason for different colours used is to aid in the readability.

Hazards associated with this task is that the work site is rather messy and an elevated possibility of trip or stumbling in the ship equipment laying on the deck is present, in addition to the grease contaminations which represent an elevated possibility of slip. The mooring wire may get stuck and jerk, hitting legs or hands of the ship crew participating in the task. See Appendix 4 the Safety Alert dated April 2016 for possible consequences of a wire jerk when work is being performed.

4.2 Suezmax tanker mooring process with steel mooring line.

To avoid undue delay in the mooring process it is paramount for the Suezmax tanker to have the mooring lines ready when arriving at the jetty, so the ship crew pulls out the mooring lines from storage drum and put to rest close to the actual fairlead the mooring line is going to be used. Prior to arrival at the jetty it is customary for the chief officer, ref Table 5 in Chapter 4.2, to check and update, if required, the JHA (Job Hazard Analysis). The JHA is a tool to facilitate and promote the safe performance of tasks which are potential hazardous to ship and terminal crew and property. The JHA is then discussed in a pre-arrival meeting onboard to warrant that ship crew, see Table 5 in Chapter 4.2 for details of the ship crew participates in the mooring process, have a clear and good understanding of the tasks to be completed and which hazards may be present in the coming mooring process. This formal way of performing a pre arrival meeting is to make sure that no part of the mooring process is overlooked.

Table 7. Summary of Suezmax tanker ship crew hours required for the mooring process with steel mooring wire.

Task	**Number of ship crew** (See Table 5 for details of participating ship crew)	**Time used in hours**	**Ship crew hours**
Preparing for mooring process performed at each port call, all lines	3	2	6
Mooring process each port call, all lines	10	1	10
Unmooring process each port call, all lines	8	0,5	4
Washing and cleaning deck area where the mooring wires were running	2	16	32

The continuous monitoring and adjusting of mooring lines taking place during cargo operation when the Suezmax tanker is changing draft, list and trim alongside the jetty is not accounted for in the above table, but on average the author`s experience estimates roughly a port stay is from first line ashore to last line cast off to be about 26 hours. Two ship crew are stationed at the deck area continuously monitoring and adjusting the lines, in addition to monitor the cargo transfer from the manifold area and performing security duties according to

ISPS. Regardless of what kind of mooring line system is in use the time consumed will be equal.

The photograph below is showing a snapshot of a mooring process onboard a Suezmax tanker poop deck. At the photograph, the ship crew stationed on the poop deck is waiting for confirmation via UHF radio from the bridge that the propeller is stopped, prior to commence lowering one of the aft breast lines to the idling mooring line boat, that will transfer the mooring line from the Suezmax tanker hull to a mooring hook on the terminal. See Table 10 in Chapter 4.8 for time used for mooring the Suezmax tanker to the jetty. See Table 5 for an overview of ship crew participating in the mooring process.

Figure 5. Ship crew stationed at the poop deck area performing mooring operation together with the terminal crew.

Source: Photograph taken by the author during a mooring operation at a terminal in Norway 29th of April 2019. The photograph is taken from the port bridgewing facing aft towards the poop deck. The author has anonymized the photograph by editing the picture. Text is added to the photograph to explain more in detail the mooring process. Text colour in yellow and black is to enhance readability. Arrows are added to point to important information, and different colours are used to enhance readability.

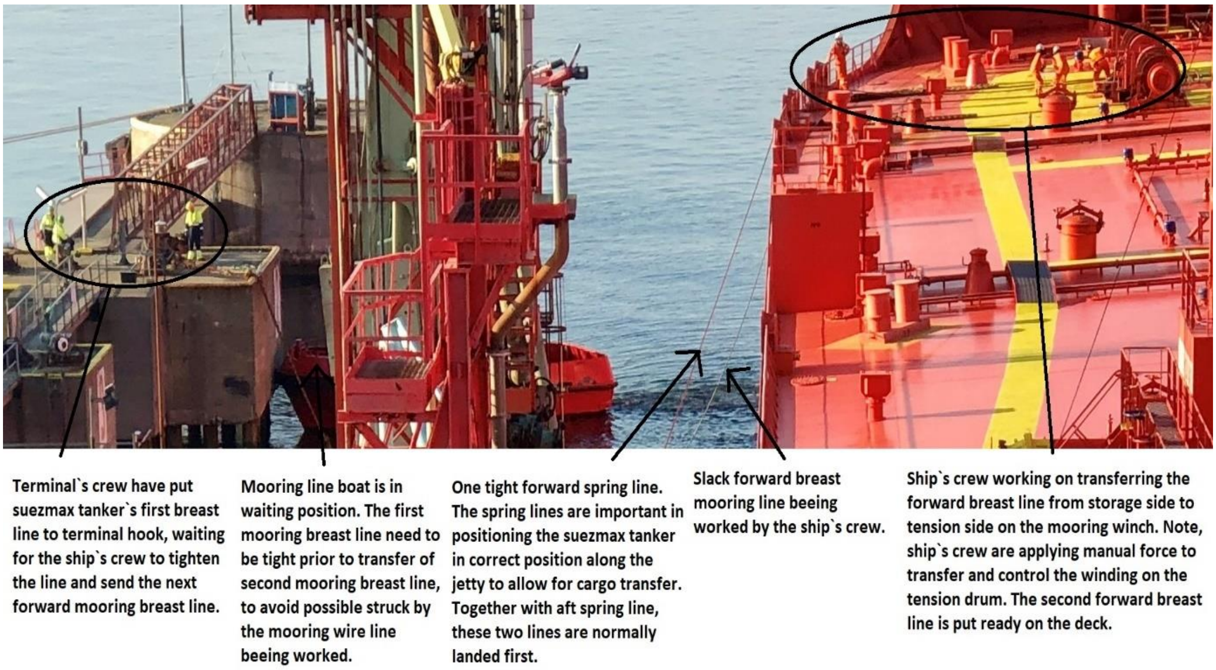
The mooring line boat is waiting for confirmation from the pilot via VHF that the Suezmax tanker propeller is stopped prior to pick up aft mooring breast line for sending ashore. Risks associated with this task is that the mooring line is to be lowered from some height, and then there will be substantial weight outside the fairlead which is a risk of the mooring line taking charge and falling either into the mooring line boat, hitting, and injuring the terminal crew stationed on deck of the mooring line boat, or the mooring line can be dropped into the sea and be entangled in the propeller of the Suezmax tanker. In Appendix 1 Safety Alert dated January 2014 covering a similar situation except for the Safety Alert is from casting off and the mooring line is entangled in the bow thruster of the Suezmax tanker when departing. Additional risk is that some of the ship crew try to stop the running mooring line by either grabbing or stepping on to the mooring line which could lead to serious injury. Sometimes the ship crew need to pull out the mooring line to have enough weight outside to let gravity pull the remaining mooring line out, this could potentially lead to back injury due to the heavy weight of the mooring line wire, see Appendix 5 Safety Alert dated August 2017 for an example of such hazard.

The three photographs below are seen from portside bridgewing towards the forecastle and the bow of a Suezmax tanker. As can be seen on the first photograph, Figure 6a., one forward and one aft spring line is made tight, implying that the Suezmax tanker is positioned correctly in relation to the terminal's cargo arms, see Chapter 3.3 case description for the safe envelop movement of cargo arms. To the right in the photograph is the Suezmax tanker manifold which the cargo arms are going to be connected to. The green circles in Figure 1 are partly (the mooring process is ongoing) illustrated in the below photograph. See Table 10 in Chapter 4.8 for time used for mooring the Suezmax tanker to the jetty. See Table 5 for an overview of ship crew participating in the mooring process. The forward and aft mooring spring line are made fast, indicating that the Suezmax tanker is in correct position to allow for connection of cargo arms. Risk associated with positioning the vessel along the berth is if the Suezmax tanker is moving too fast and the ship crew try to stop the movement by tightening the mooring spring line can result in mooring line brakeage and the dangerous snapback, see Chapter 2.5.2 and 2.5.3 regarding snapback hazards. In Appendix 2 Safety Alert dated March 2015 a shifting or warping, see Chapter 4.7 at the berth taking place with a different type of tanker resulting in serious injury to ship crew from snapback relating to mooring process.

Figure 6a. Suezmax tanker port side alongside terminal, mooring operation in progress.

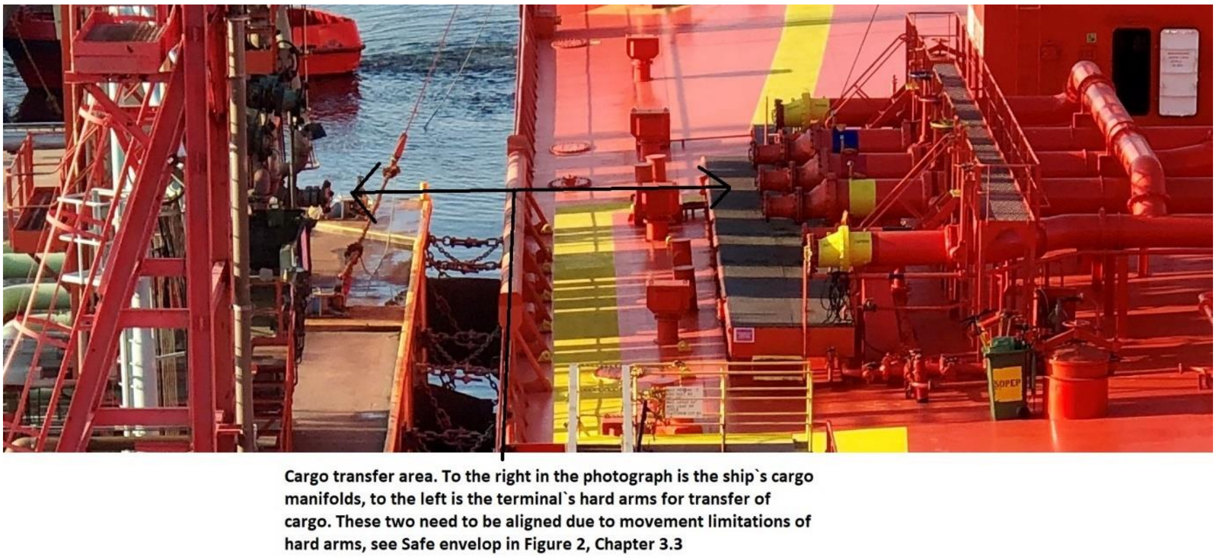
Source: Photograph taken by the author during a mooring operation at a terminal in Norway 29th of April 2019. The photograph is taken from the port bridgewing facing forward towards the forecastle and the bow.

Figure 6b. Detailed view of forward mooring process.



Source: A clip from Figure 6a. The arrows, eclipses, and the explaining text by the author.

Figure 6c. Detailed view of cargo transfer area.



Source: A clip from Figure 6a. The arrows and the explaining text by the author.

The washing and cleaning post departure are required due to grease debris from the running wires are set of to the deck areas and mooring fairleads resulting in slippery surfaces, which are an elevated risk for slip, trip and fall of personal onboard the ship, which might lead to ship crew injury. In addition, the wires very often pull seabed sediments on to the deck when the wires are hauled onboard the Suezmax tanker during unmooring process, these sediments also need to be removed, to maintain the good cosmetic appearance of the Suezmax tanker.

4.3 Suezmax tanker using HMSF line as mooring line.

The author did not have any access to a Suezmax tanker utilizing fibre lines or HMSF lines and have not collected any data for such, however it turned out during the author`s time onboard the Suezmax tanker during observations and discussions with the ship crew that some of them had previous experience with fibre rope moorings of Suezmax tankers. During these discussions the ship crew unison told the author the following benefit with such ropes are: "*very easy to handle and to work with. No additional cleaning is needed, and no additional paintwork is required, and the ropes are very light to work with*."

4.4 Head of department of marine transportation organizer perspective of the mooring operation.

The first interview, a pilot interview, was done 14th of December 2018 between 09:00 – 10:00 at the respondent's office building with the head of the department organizing marine transportation. In the perspective of this thesis, the head of marine transportation organizer can be looked upon as both an organizer by giving speed and destinations instructions to the Suezmax tankers, or as a customer measuring the time performance delivered by the Suezmax tanker. From Chapter 2.1 lean theory for use in Suezmax tanker mooring process, Rolfsen, (2018) who point out, find the value value perceived by the customer, and in this thesis the author is considering time is value. Further Rolfsen, (2018) highlights that the value stream generating the value must be identified, the author is in this thesis considering the mooring process as the value stream. To improve the value stream the waste must be reduced or cut by applying continuous improvement cycles. (Rolfsen, 2018).

Below is an extract of the key points captured from the head of marine transportation organizer. Focus area are cost control in operation and to meet mandatory governmental regulations by being proactive. It is a capital-intensive industry where upgrades, alterations and changes of hardware are costly and time consuming, planning phase is normally between two to three years, while for the execution we talk months. The company welcomes new proven and tested technologies but are not first movers.

The branch office of this company is given right of self-determination, meaning they can forge their business to enhance profit as they see most convenient without interference from main office. The chosen business strategy is by offering flexible solutions to customers and by providing "all inclusive" strategy for their customers, the company add value to their own supply chain by being in control of each and every step from the oil extraction too consume. To promote such a strategy, tankers are mainly hired on T/C (time charter) basis, leaving the marine transportation department in control of speed and destination instructions to the employed tankers. The company's expectations to tankers employed is by verifying quality by checking vetting reports, efficiency is measured by time consumed for loading and discharging of the tankers. There is a focus on fuel consumption and how to reduce the consumption either by engine and hull optimizing or alternative fuel.

Congestion at terminals happens every now and then, and one of the reasons can be due to periods of bad weather or aging tonnage not delivering according to expectations, can make it a challenging endeavor to meet demand for marine transportation. One critical part as such is the berthing time and time alongside the jetty. The optimum use of the jetty is crucial to avoid any bottleneck in this part of the chain. Demurrage rate can force shifting in the jetty plan. Inventory is another crucial factor needed to be considered when planning the berth line up. It could be storage tanks that are full, or storage tanks that are empty need to be refilled, so it is like solving a solitaire.

The efficiency on the tankers is closely monitored such as the pumping rate, the mooring equipment, and the manifold layout. The transportation department gets feedback from terminals on how the operational performance of the tankers are and utilize this information by closely follow up the performance with the suppliers of marine transportation.

4.5 Terminal crew perspective of the mooring process.

Below is a summary of the mooring process based on an interview with a terminal crew actively participating in mooring processes, on the 4th of September 2020 performed at the authors address over a cup of coffee. The interview, the transcribed interview and the resume is all done by the author.

Regardless of steel wire or HMSF the line up with mooring lines for the Suezmax tankers are normally 4-2-2, that means 4 bow and 4 stern lines, 2 breast lines forward and 2 breast lines aft, and 2 spring lines forward and 2 spring lines aft, a total of 16 lines. The lines landing first is the forward and aft spring line. When the arriving Suezmax tanker is closing in on the terminal berth two small mooring boats come out to the ship side of the Suezmax tanker arriving and pick up spring line forward and spring line aft, if it is steel wire and soft tail the boats take only one line at a time, however if it is HMSF line the mooring boat can take both lines in each end and bring them to the jetty. At the jetty there are winches located in close proximity to each mooring hook where the terminal crew at the jetty send a messenger line to the terminal crew in stationed in the mooring line handling boat, one of the terminal crew in the boat then tie the mooring line and the messenger line to each other and signals to the terminal crew on the jetty to start hoisting the mooring line(s). When the eye of the tail is on the jetty the terminal crew stationed there put the eye on the mooring hook and signals to the Suezmax tanker to start tightening the mooring line. In the meantime, the mooring line boats are moving away to avoid being captured between the Suezmax tanker and the jetty. The Suezmax tanker is then pushed completely towards the fenders with the tugs and the spring lines are used to position the Suezmax tanker in the correct position for the transfer of cargo. When position is confirmed good, the remaining mooring line is transferred in the same manner.

On some occasions one of these mooring boats might be out of service due to maintenance or breakdown, resulting in a prolonged mooring process, as one boat need to do the job of two boats.

The mooring equipment at the terminal is maintained by terminal crew other than terminal crew being responsible for the mooring operations. The mooring boats are owned by a boat owner, renting these boats to the terminal, and the boat owner is using their own crew for maintenance and terminal crew being responsible for mooring operation is operating the mooring line boats. The author was not able to get any in depth details of the maintenance required on the jetty mooring assets, nor the mooring boats.

The terminal crew working with mooring operations on the jetty are mooring and unmooring different types of tankers between two and four times a week, indicating they should have vast experience in the mooring process, but even so, formalised risk reduction measures are utilized to deal with potential hazards. Nevertheless, most hazards experienced is related to communication errors between the ship crew on board the Suezmax tanker and the terminal crew at the jetty. Hazards encountered is such as pulling in mooring line when it is supposed to be slacked. Another issue is the speed of the movement of the Suezmax tanker to be moored, it might result in trapping the mooring line boat or to put excessive load on lines that are becoming tight with the risk of being parted, snapping in both direction with high energy. Further, if the Suezmax tanker are in possession of a bow thruster and are using it without communicating the use to the forward mooring boat it can result in hazardous situation as the mooring line boat is pushed like a cork in a bathtub. In extreme cases the mooring line might be caught in the bow thruster, the risk is especially high with steel wire and soft tail. The same can happen aft with the main propeller, the propeller is supposed to be stopped when the mooring line boat start to work with the breast lines aft, but if for some reason the main propeller is put to use and there is excessive slack on the aft breast line it might be caught in the propeller, resulting in damage to the Suezmax tanker, the terminal jetty and the mooring line boat.

4.6 Pilot perspective of the mooring operation.

The resume below is based on the authors interview guide emailed at 15th of September 2020 to a special trained pilot performing mooring and unmooring of Suezmax tankers to an oil tanker jetty. The response from the pilot was emailed to the author 21st of September 2020.

The response from the pilot is based upon procedures from the oil terminal which the pilot is special trained to moor and unmoor Suezmax tankers and experience gained through the capacity as a special trained pilot when mooring and unmooring Suezmax tankers.

Suezmax tankers are normally equipped with mooring line wires and tails connected by a joining shackle, then the mooring line boats pick up only one line at a time, but if the Suezmax tanker is equipped with mooring line HMSF ropes, the mooring boat can handle two lines at the same time.

4.6.1 Comparison of mooring line wire versus mooring line HMSF rope.

Wires are much heavier to handle. Just to get the joining shackle through the fairlead of the Suezmax tanker is sometimes challenging for the ship crew. The steel mooring wires are heavy and at the same time the mooring line boat is waiting. When mooring line boats do the pick-up, they normally bring the tail and joining shackle onboard before sailing towards mooring dolphins. While with mooring line HMSF ropes, the mooring line boat can pick up the mooring lines without stopping. The ship crew can easily slack out HMSF line in a controlled manner and at a higher speed than with wires.

With HMSF ropes all parts of the transfer are faster. This involves lowering of the lines to the mooring line boat, bringing the HMSF mooring lines to the mooring dolphin by boat and hoisting the HMSF mooring lines from the mooring line boat to the hook ashore.

Another factor is the fenders on the jetty. Mooring wires can sometimes get stuck under the fenders if the mooring wire is kept slack. In this case tugboats must stop pushing, change to a pull position to stop the Suezmax tanker movement towards the jetty and in some instances pulling the Suezmax tanker slightly off the jetty to have the mooring wire free from obstructions before the tug are repositioned to a push position for pushing the Suezmax tanker back alongside the jetty fenders. Depending on the situation this will extend the mooring operation with 5-15 minutes. HMSF ropes are floating and do seldom cause any problems related to the fenders.

In general, the ship crew seems to be more comfortable with handling mooring HMSF ropes compared to mooring wires. Both slacking out and heaving up mooring lines, are normally done at a higher speed with mooring HMSF ropes compared to mooring wires. Handling of mooring wires also requires higher numbers of ship crew to participate in the mooring operation.

4.7 Supplier of automated mooring perspective on the mooring process.

The author did a video interview on the 6th of October 2020 from 13:00 to 13:35 due to time and travel restrictions related to Covid-19 with a sales representative from a leading company suppling automated mooring systems. The interview was audio recorded at the cellphone of the author and transcribed by the author into a word file and stored at the authors laptop. Due to some unclarity in the data captured from the Teams interview a follow up telephone call was done at 13th of October at 12:00 to 12:20, and now the author used pen and paper to take brief notes during the telephone call, and just afterwards made a summary by writing in word and store it on the author`s laptop.

The first Nordic automated mooring system was installed in Denmark, 2008 and do not require any shore personnel. Vessel types and metrics need to be defined at the design stage, all vessels meeting these criteria can use the automated mooring system. When the automated mooring system is being assessed, the historic weather data and real weather conditions which the terminal owner consider it safe to have a tanker alongside performing cargo operation forms the basis for the required system metrics, and hence the system layout and the price for the automated system is dependent on these metrics. OCIMF has approved the automated system as novel but has not given recommendation to its members to install the automated mooring system.

As with all kinds of mechanic systems, maintenance is required, but carried out and followed up from the OEM (Original Equipment Manufacturer) the expected uptime will be from 99,5% - 99,8%. Table 8 is displaying that only one service crew is needed to maintain the automated mooring system, but human labour is a major part of the total value delivered in services (Ellram et. al., 2004).

Table 8. Maintenance required for automated mooring system.

Task	Frequency of task	Number of service crew	Time usage in hours	Service crew hours
Visual check, lubrication, and test of the system.	Every 3rd month	1	6 hours/unit	6 hours/unit
Change of consumables	Every 6th month	1	Included in above	Included in above
Oil check or change	Every 12th month	1	Included in above	Included in above

Compiled by the author in a follow up telephone contact meeting 13 Oct 2020 with automated mooring representative.

When a ship is due to call a port with installed automated mooring, no preparations are needed; all can be automated via internet and AIS for the units to be used. Ship and terminal crew are not involved in the mooring process except from the bridge complementary for manoeuvring the ship to correct position and one terminal crew to communicate the correct position to the bridge of the berthing ship. A service provider is only present during maintenance and thus the number of ship and terminal crew involved in the mooring process who are at risk if something is going wrong is very limited.

The mooring itself is done with vacuum pads, the ship is held against the fenders with tugboats and when the ship is more or less in position a terminal crew or a pilot who has an iPad or similar device, hit a button called moor, than it takes only a few minutes, and the ship is safely moored, due to vacuum the pads are creating between the ship hull and the pad. As the cargo operation progress, there is a significantly change in draft and trim and smaller changes to the list, so the system needs to act to facilitate the movement of the ship and at the same time keep the ship safely moored. To meet these requirements the pads can move up or down plus minus one meter, but when that is not enough, then the system will need to do a stepping. A stepping is done by the system automatically by releasing one pad at a time, repositing and then attach to the ship hull. Then the next pad is doing the same and it can continue like this for unlimited number of steps. To counteract listing issues the vacuum pad itself has plus minus four degrees pivoting point limit. In addition, the system can warp (shift position along the berth), to centre the Suezmax tanker manifold with the terminals cargo arms safe working envelop, see Figure 2 in Chapter 3.3.

There is a time saving potential with this type of mooring process for all parties involved. The pilot can disembark as soon as the gangway is landed onboard, the pilot does not need to wait for all lines to be made fast, which normally amounts to about one hour. The tugboats can be dismissed as soon as they have got their tug lines since they do not need to wait for all mooring lines to be made fast. The ship can commence cargo operations earlier than compared to mooring lines. The possible time saving in the mooring process could lead to less fuel consumption since engines can be stopped earlier.

4.8 Summary of all findings emerging from the collected data.

Table 9. Summary of findings evolving from collected data.

Mooring Concept	Responsibility of mooring gear	Weather criteria	Author's evaluation of mooring system concepts	
Steel wire	Joint responsibility, where tanker supplies lines and terminal supplies mooring boats and shore hooks and pulleys.	Standard OCIMF, see Chapter 2.5 for full details of weather criteria	Proven system Widespread in use	Support
			Heavy weight Resource demanding Time consuming Safety issues	Weakness
HMSF	Joint responsibility, where tanker supplies lines and terminal supplies mooring boats and shore hooks and pulleys.	Standard OCIMF, see Chapter 2.5 for full details of weather criteria	Light weight Time saving	Support
			Less resource demanding Safety issues	Weakness
Automated	Terminal supplies and operates the automated system.	Historical and actual and to customers specification	Time saving Limited safety issues	Support
			Tanker design criteria Cost of installation	

			Split of cost and benefit challenge Electrical power availability	Weakness

Source: Collected data by the author

Summary of factors that requires more time when handling mooring wire lines versus HMSF mooring lines:

- Lowering of mooring lines to the mooring line boat.
- Transfer of mooring lines by the mooring boat from ship to shore.
- Heaving up the mooring lines to the mooring-hook ashore.
- Tightening up the lines on board the Suezmax tanker, due to ship crew handling the mooring winch at lower speed.
- Mooring boat only handles one mooring line at a time.
- Mooring line can be stuck under the fender, but this happens very seldom, but a delay of between 5 -15 min might be expected.

Table 10. Summary of time consumed and time saving in hours for the various mooring concepts.

Mooring concept	Minimum time consumed for mooring	Maximum time consumed for mooring	Average time consumed for mooring	Saving of time compared to steel mooring line
Steel mooring line	0,75 hrs	1,25 hrs	1,0 hrs	0
HMSF mooring line	0,42 hrs	0,67 hrs	0,5 hrs	0,5 hrs = 30 min
Automated mooring	0,017 hrs	0,1 hrs	0,05 hrs	0,95 hrs = 57 min

Source: Collected data by the author

Table 10 shows a great time saving potential if mooring concept is switched from steel mooring line concept to a HMSF mooring line concept of about 30 minutes and a further time saving potential of 57 minutes if automated mooring concept is used versus the steel mooring concept. The automated mooring concept is representing a time saving potential of 27 min compared to HMSF mooring concept.

5 Discussion

This chapter discusses the findings presented in Chapter 4, Results, together with relevant literature presented in Chapter 2, Literature review. The author has divided the discussion chapter into three chapters with additional subchapters. The first chapter is discussing the safety of ship and terminal crew in general, (the management system used to enhance the safe performance.) Chapter two is a discussion of the mooring process with mooring lines, in an operational view, divided into two subchapters, the first one is concerning steel mooring wire line and the second HMSF mooring line. The third chapter is a discussion of emerging mooring technology. Lean practices discussed in Chapter 2.1 are incorporated in the discussion chapter where the author sees it fit to expand and give a new view angle on the mooring process being studied. The author is focusing on assessing and to discuss strength and weaknesses in the findings.

5.1 Safety of ship and terminal crew.

Safety of ship and terminal crew is one of the paramount goals in the tanker shipping industry. In this context safety is considered as no harm, injuries, or fatalities to ship and terminal crew and no damages to Suezmax tankers nor terminal jetties, related to the work performed in the tanker shipping industry. OCIMF is threating safety among their top priorities and in published books we can read: "*You stand a greater risk of injuring yourself or a shipmate, during mooring and unmooring operations than at any other time*." (OCIMF, 2005 p. 63). To meet or mitigate the hazards and complexity connected to safety of ship and terminal crew, the industry has developed some risk reduction tools such as e.g., JHA, to identify risks and mitigating actions. In the tanker shipping industry, the formal safety assessment like risk analysis and assessment is widely in use and accepted by ship and jetty operators and are seen as a promise for a more efficient control of risk. This way of approaching the risks is questioned and challenged by some professionals who argues that such methods can oversimplify the process, different failure combinations are overlooked, and the human element is not properly addressed in the process (Kristiansen, 2005). By addressing human element appropriately (Crowl,2007) an important safety element is incorporated in the task at hand which can improve operating effectiveness, meaning a time saving potential is present, thus adding value to the marine transportation service, while on the other hand if an injury to ship or terminal crew occurs or damage to Suezmax tanker or terminal jetty happens will prolong the mooring process, consume more time, thus adding waste due to time lost. The quality performance, by adding value equals time saving, of the provided marine service is therefore closely linked to safety (Österman & Osvalder, 2012).

Regardless of which formal assessment and risk mitigation tools is used, some residual risk will remain (Kristiansen, 2005). Accidents need to be viewed as a process where the activity, in this case a mooring process, is exposed to hazards and complexity and if not the procedural measures or improvement in equipment design are not fully realised, then a small initiating event together with a human element and the complexity of the process to be performed constitutes the casual network that might lead to an accident (OCIMF, 2018 & Kristiansen, 2005).

Investigations of some incidents and accidents on ships have identified that measures to protect the health and wellbeing of ship`s crew were not fully implemented (OCIMF, 2018). Studies of accidents and incidents demonstrate that investing in the right design upfront can significantly enhance the health and wellbeing of personnel in the short term and save the cost of solving a problem later (OCIMF, 2018). Fundamental innovations have been driven by legislators (Lorange, 2009) e.g., the requirement for double hull tankers vs single hull, could such innovation be driven by legislators in the case of mooring processes? With innovation in shipping, it seems to be a stronger first-mover advantage (Lorange, 2009). The author think a paradox is that Kristiansen (2005) argues that there is an understanding of why accidents happens, involving ship and terminal crew, the complex task at hand, that there is a tendency to take a more narrow view both in design and planning of mooring processes.

5.2 Exiting mooring system.

In this chapter the author will discuss the two types of existing mooring line systems presently in use. The steel wire mooring lines with soft tails have been in use for decades, but HMSF mooring lines with soft tails are increasing in usage. Table 9 in Chapter 4.8 will be the starting point for the discussions. The above-mentioned table is displaying weather criteria design is equal for both the exiting systems, and the Suezmax tanker and terminal are sharing responsibility for the mooring process.

5.2.1 Steel wire mooring line.

The steel wire mooring line is the most common type of mooring system used for Suezmax tankers. The steel wire mooring system has during the years proven its value, and it is still in use even new technologies have become available for making light weight line with the same type of physical properties as steel wire mooring line. There are quite a few factors supporting the replacement of steel mooring lines with HMSF mooring lines. Table 10 is displaying time consumed for the mooring process with steel mooring wire line, HMSF mooring line and automated mooring. The steel mooring line is forming the base line on which the HMSF mooring line and automated mooring are compared to. Table 10 displays a time saving potential, which in lean practices is considered as value added by a change in type of mooring line used or a change in technology. See Chapter 2.1 for a discussion of lean processes.

The major drawback factors of steel mooring lines are due to weight and maintenance regime required to prolong the operational life. Due to its dead weight the number of ship crew to handle the line is high in all lifespans of the wire, in this context, from the purchased steel mooring wire line is received on board, stored, brought out from storage, installed, maintained, used, cleaned, uninstalled, and disposed of to a reception facility. In a lean perspective this is not a good way to work, as one of the pillars in lean practices is that unnecessary movement should be avoided as this is considered waste (see Glossary for what is considered waste in this thesis). The above mentioned is just a brief overview of all the moves needed, and due to the dead weight, cranage and winches are utilized to aid the moving of steel mooring wire line. Further see Table 6. Summary of Suezmax tanker mooring equipment maintenance tasks and ship crew hours needed to complete the mooring equipment maintenance tasks, to get an overview of ship crew resource consumption. As the table show, it is resource demanding to maintain the wire system (see in Appendices chapter for details of various maintenance tasks required), and the complexity of performing such task. This is results from just a single ship, imagine adding up all Suezmax tankers trading today.

In an extreme lean perspective, we can consider the wire only doing its job when it is already deployed and made tight, all maintenance and mooring movement could be considered waste. In Table 7. Summary of Suezmax tanker ship crew hours required for the mooring process with steel mooring wire is an overview of resources required from the Suezmax tanker to perform the mooring process and keeping in mind this is just for one single port call, imagine one ship doing 30 -40 port calls a year, then all Suezmax tankers doing 30 – 40 port calls. The numbers keep on adding up, this table is not considering the number of terminal crew that is participating, so the actual number is higher.

As discussed in Chapter 5.1 Safety, it cannot be guaranteed that the ship and terminal crew do the mooring process correct the first time, even utilizing formal assessment and meeting with ship crew upfront of the mooring process. The industry approach to mitigate risks associated with mooring processes is formal assessment to enhance the safe performance, contradictory to another pillar of lean principles the idea of performing it correct the first time, poka-yoke (Fujimoto, 1999), has the meaning that processes or products should be designed in such a way that physical errors cannot happen by simplifying and designing the mooring equipment in such way that the ship and terminal crew cannot do it wrong.

Mentioned earlier in this chapter, one of the major drawbacks with the steel wire rope is the dead weight. Known incidents such as the wire getting caught underneath fenders is the nature of its dead weight, but human element are the reasons behind these types of incidents, and to recapitalise Österman & Osvalder (2012) who claims that quality of the provided maritime transportation is closely linked to safe performance and in a lean context reduce waste generated, e.g. time delays in mooring process of Suezmax tanker when the mooring wire get underneath the jetty fenders causing a delay of between 5 min to 15 min, see Chapter 4.8 Summary of all findings emerging from the collected data.

Through the SIRE vetting system OCIMF is addressing human element issues by stating minimum requirements in the tankers crew competence matrix, and these are checked during vetting inspections onboard. This approach is in line with Kristiansen, (2005) who claims that an acceptable safety standard on board the Suezmax tanker is dependent on that the company running the Suezmax tanker has a sound economy enabling the company to work systematically and continuously with safety-related matters such as training of personnel, developing better technical standards and improving management routines.

Miscommunication may happen within the Suezmax tanker to be moored, or between the Suezmax tanker and the terminal, in this case both the terminal crew and the mooring line boat crew (terminal crew). The tugs are let out of this thesis, but it should be mentioned that it could be a contributing factor to escalate the miscommunication as it is using the same VHF channel to send and receive information e.g., the tugboat crew (human element) may not understand the message given, or executing wrong command, putting the mooring line boat crew who are transferring ship steel mooring wires to the terminal in a hazardous situation. In short miscommunication between or within any participating crew have a significant damage potential, and can be considered as human element, see Chapter 2.3 to clarify human element.

5.2.2 HMSF mooring line.

With new material types and new ways of producing synthetic fibre lines new mooring lines with the similar physical properties as steel mooring wires are being manufactured. It is widely in use on smaller tankers. The HMSF mooring lines have some advantages compared to steel mooring wires. The major ones are the physical property of being light weight, it requires fewer ship and terminal crew to handle, and the mooring line boat can handle two lines at the same time, thereby reducing the required number of transfer runs to be performed. As a result of fewer transfer runs and the light weight, a time saving potential is present compared to steel mooring wire, and the saving potential might cut the mooring process time down to half, as illustrated in Table 10.

The number of potential delaying factors such as rope in propellers or underneath the fenders are not present with HMSF mooring lines, as these types of ropes float. In addition, when the mooring lines are being cast off and pulled onboard the tanker, no additional cleaning is required, as these mooring lines do not pull seabed debris onboard. The mooring line boat is not contaminated with grease debris resulting in slippery surfaces and elevated risks of slip, trip and fall, and the mooring line boat do not need to collect some meters of the rope inside the boat since it is floating and light weighted. Hence, it can then start the transfer immediately after the mooring line is grabbed by the mooring line transfer boat.

When the HMSF mooring line is received onboard it still needs to be transferred to storage, installed, inspected, deployed, and discarded of in the same manner as steel mooring wire. For the Suezmax tanker a time saving potential is present in the maintenance process, the deployment process, and after the departure from port since no additional cleaning is needed to wash seabed residues or grease contaminations set of too deck or fairleads. This fits well in a lean perspective, as waste, see Glossary, are removed, and the ones benefitting from this is the ship crew, and to some extend the mooring line boat crew which do not need to clean grease debris from transporting of steel mooring wires. The time saving present in the mooring process is benefiting both parts as the cargo operation may start earlier, giving a larger window for operation if bad weather is forecasted. In addition, for the Suezmax tanker it has a time saving potential onboard due to less (unnecessary) work incurred with HMSF mooring lines than with steel mooring wire line both prior to and after departure from port. See Chapter 4.8 under the: Summary of factors that requires more time when handling mooring wire lines versus HMSF mooring lines, for more details of which steps in the mooring process time saving is present. The time saving potential in the mooring process indicates that the Suezmax tanker can stop their engines earlier, and thus reduce fuel consumption.

The risk of miscommunication is present, (see chapter 5.2.1 Steel mooring wire the final section), but compared to steel mooring wires, the risk is reduced due to lower dead weight of the HMSF mooring lines. The risk of high tension and parting of the line is still present (see Appendix 2, Safety Alert dated March 2015, note this is not a Suezmax tanker, but another type of tanker, but similar in physical size as a Suezmax tanker and considered by the author to be a valid example).

5.3 Emerging mooring system.

The automated mooring is spreading in other shipping segments such as container terminal and liner services, the automated mooring system is even in use in the locks to the Great Lakes and in a dry bulk terminal. The system is new compared to traditional ways of performing the mooring process, and it presents a different way to perform the mooring process. We might say OCIMF has a conservative way of approaching the mooring process as the basic metrics for the mooring equipment is given through a standard weather situation where the mooring system should withstand the environmental forces acting upon the moored Suezmax tanker. On the contrary, the automated mooring system manufacturer is requesting the potential client to define the weather condition in which weather condition the ship is expected to stay moored and when it is due to vacate the berth. The automated mooring manufacturer is then looking at the historical weather data and the location of where the berth is going to be situated, and finally calculate the required mooring arrangement needed to meet the weather criteria set out.

OCIMF has acknowledged the automated mooring as a novel way of performing the mooring process in the Suezmax tanker terminal interface. Another supporting argument is a tremendous time saving potential (see Table 10, where about one hour is possible to save, significantly adding value to the process). In addition, the automated mooring process greatly reduces the risks of accidents, since no ship and terminal crew is manual handling any mooring equipment. All this is being organized from a remote location, such as the manoeuvring bridge wing of the Suezmax tanker to be moored, and a terminal crew advising the correct position.

A limitation of this system is that only Suezmax tankers fitting to the design criteria can use it, and if not, they will need to use the traditional way of performing the mooring process.

To make sure the mooring system is performing as expected regular maintenance is required. Maintenance is provided by a service technician provided by the automated mooring equipment manufacturer. It is crucial that such services are performed with good quality; human labour is a major part of the total value delivered (Ellram et. al. 2004), to avoid any malfunctions or breakdowns. Port equipment maintenance needs will generally be proportional with the degree of selected sophisticated solution (Thoresen, 2003).

In contrast to existing mooring system where the jetty or terminal operator only assume responsibility for mooring equipment located at the landside, and the ship operator assume the responsibility for the mooring equipment which is located onboard the Suezmax tanker, the automated mooring system shifts the responsibility of the mooring process solely to the jetty or terminal operator, see Table 9. The shift in responsibility is a major challenge as the ship operator is free from responsibilities and the terminal operator is resuming all responsibilities with the mooring process. The law of the market can easily discourage unconventional thinking, but according to Lorange (2009), these established truths in the maritime industry should be challenged.

As mentioned earlier in Chapter 5.3, the safety of the ship and terminal crew are significantly enhanced by not being present in the hazardous area. The impact of the human element is reduced and the complexity and challenges in communication and execution are reduced, making the mooring process more transparent. These benefits are promoting OCIMF greatest concern, the safety of ship and terminal crew. In a lean perspective, a lot of waste (see Glossary of meaning of waste), is reduced, or eliminated due to redesign (see Chapter 2.1, of the mooring process and then adding value, by saving time and consuming less ship and terminal crew, to execute the mooring process).

The time saving potential adds value to the mooring process by allowing for stopping the engines earlier, tugboats can be dismissed earlier, and the pilot can be dismissed earlier. This represents a potential for saving both time and fuel. Other advantages are shorter time is needed for a shift in jetty plan, see Chapter 4.4, 4^{th} section, resulting in more time available for cargo operations. In addition, the terminal is reducing the possible wastes of mooring lines, (see Chapter 4.8 in section, Summary of factors that requires more time when handling mooring wire lines versus HMSF mooring lines).

Other unfavourable factors of the automated mooring system are the system itself has a limitation of 4 degrees pivoting to compensate for Suezmax tanker listing during cargo operation. This pivoting limitation is within normal listing of a Suezmax tanker during a cargo operation. Further, mooring cannot be done if there is no electrical power available, but in such an instance the author presumes that no Suezmax tanker will be moored. However, if already positioned at the jetty, the Suezmax tanker will stay moored but the cargo operation will be ceased. The automated mooring system need backup power available in case of loss of main power source to have the pads operational. If no air leaks are present at the pads, it is possible to stay moored along the jetty but if an air leak is present the Suezmax tanker needs to vacate the berth. On any occasion the status of the automated mooring system is real-time monitored and will provide information that will assist in decision whether to stay or to vacate.

6 Conclusion

The research questions in this master`s thesis are:

1) What is the mooring process of Suezmax tankers?

2) How can the mooring process of Suezmax tankers be improved?

The first research question is enlightened and analysed through Chapter 4 Results, see Figure 6 and Table 9. The mooring process of Suezmax tankers is a complex, procedurally controlled, dynamic, demanding process, requiring ship and terminal crew to execute and communicate with respect and understanding of each other’s challenging and routine tasks to safely accomplish.

The second research question is concerning improving the outcome from the first research question. This thesis has focused on implementing lean principles in the mooring process to identify improvements. The findings contribute to the following improvements in the mooring process:

- A time saving of 30 minutes in the mooring process when HMSF mooring line is used compared to steel mooring wire line.
- A reduction in time spent on maintenance onboard the Suezmax tanker when HMSF mooring line is used compared to steel mooring wire line.

The time savings represent saving work hours for the Suezmax tanker crew, which could lead to less use of overtime and to meet rest hour requirements, thus enhancing the safety.

A more radical approach to improve the mooring process is the automated mooring system that redesigns the mooring process.

- The complexity of the mooring process is reduced, one ship or terminal crew performing the mooring process with a wireless remote operated device.
- A time saving potential for the mooring process of approximately 1 hour compared to steel mooring wire and about 30 min improvement compared to HMSF mooring line is identified.
- Most of the ship and terminal crew is removed from the hazardous area, and the remaining ship and terminal crew are at remote locations away from hazards, significantly enhancing the safety of ship and terminal crew which is among the greatest concerns for OCIMF.

7 Recommendations for further studies

This thesis is not considering any cost in terms of money, but in real world context money is important in all aspects of business. With automated mooring, this thesis has identified a challenge in the cost and benefit splitting of the mooring process, see Table 9, since all cost are incurred to the jetty operator and all cost saving are incurred to the Suezmax tanker operator, this should be studied closer by applying supply chain management measures such as alignment, incentives, and motivation to enhance the cost and benefit split challenge by the involved parties, or if legislators need to drive this innovation? Keep in mind, Lorange (2009), with innovation in shipping it seems to be an advantage for the first mover.

A second study is to work towards the Suezmax tanker in identifying the full outcome of all timesaving potential identified in the mooring process when changing from steel mooring wire line to a HMSF mooring line.

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Appendices

Appendix 1. Safety Alert 14 January 2014 Mooring operation. The author has anonymized the paper document prior to scanning and attaching.

Safety Alert

Date of Incident	**14/01-14**
Subject/Topic	**MOORING OPERATION**

Summary:

Vessel was moored to Jetty # 1 [redacted] port side alongside.
During unmooring operation the vessel had, as per Pilot advice and Master orders slackened just the starboard headlines. OOW could visually confirm the starboard headlines released by shore personnel, and then he went over to starboard side to monitor how the mooring lines were retracted. The OOW did not, at that time, have any visual contact with shore personnel, due to BLS house obstructing line of sight.

When starboard headlines were retrieved and confirmed secured, the OOW went over to port side to proceed with unmooring where he noticed that the port headlines also were released.
Bridge was immediately notified to stop the bow thrusters, which the Master did immediately with pitch set to zero.

When the port headlines were retrieved, one of the two headlines was observed damaged without the wire eye, soft tail and Tønsberg shackle. This was reported to the bridge.

Once fore and aft team were given clearance to let go all lines clear, the thruster was again used to maneuver the ship sideways, and then for turning the ship around.
After few minutes it was reported by Chief Engineer that bow thruster No: 1 had stopped, and was not possible to restart again, as the pitch of the bow thruster was not set to zero. Information regarding thruster running or not, is not possible to obtain visually from the bridge wing manoeuver console.

After additional attempts to restart the thrusters without any success the decision was taken to proceed to anchorage to be able to arrange for divers for under water survey for the bow thrusters.

Consider

- Each vessel to review the mooring of vessel procedure [redacted] during their next HSEQ meeting, and to appropriate update their own JHA for mooring operation to reflect the key elements of the incident.
- Discuss your onboard mooring practice to be able to have enough people fore and aft for safe mooring operation, and always have one person with visual contact with shore side.
- Master to inform Pilot during Master/ Pilot exchange to provide necessary information to shore personnel NOT to release any mooring lines without visual confirmation by vessels crew.

Remember! "No job is so important or urgent that we cannot take the time to do it SAFELY"

Appendix 2. Safety Alert March 2015 HMPE mooring line parting causing serious injury. The author has anonymized the paper document prior to scanning and attaching.

Safety Alert

Date of incident	**March 2015**
Subject/Topic	**HMPE Mooring Line parting causing Serious Injury**

Purpose

The aim of this Safety Alert is to highlight a recent mooring incident which occurred on a [redacted] operated, Nakilat project Q Flex vessel which resulted in very serious injury to one individual. It should be noted that the actual incident is still under extensive investigation and once concluded, will be available to the public however the below information is provided solely to precaution against safety until the full investigation is concluded and released to the public.

Overview

The vessel was berthed port-side alongside a Terminal. The vessel was safely moored to the Terminal but the mooring team had returned to stations to adjust the position of the vessel. There was one man driving the mooring winch motor from the winch controls and a relay man situated against the bulwark (near UF1 in below Figure) who was in sight of the Officer in Charge and the winch controller.

The Officer in Charge was located at the position as depicted in Figure 1 below. From this position, he was able to see the Relay Man. The mooring line was a HMPE mooring line equipped with a 22m Euroflex mooring tail and was secured to the shore hook. Whilst being tensioned by the mooring team, the line parted roughly in the position shown in Figure 1 below.

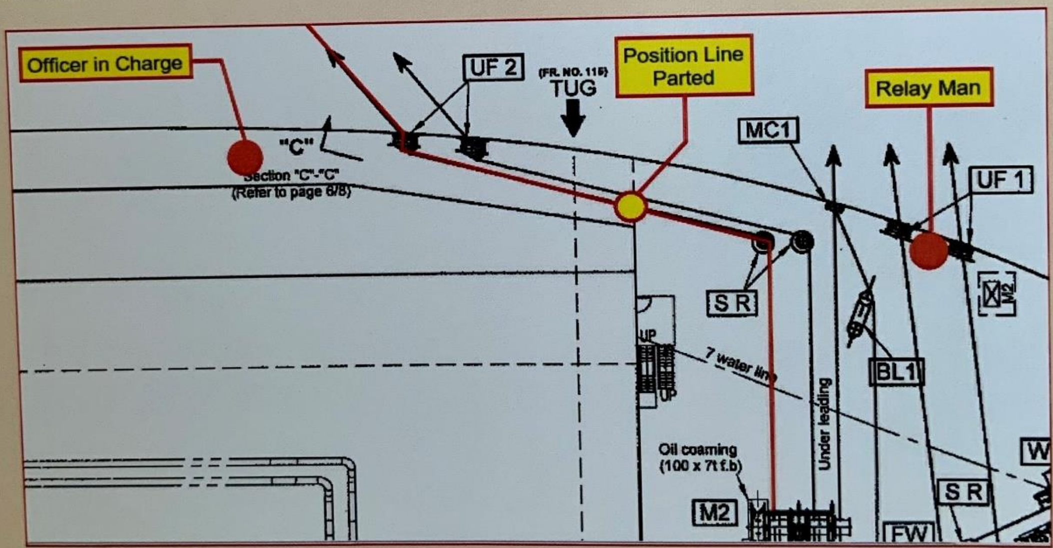


Figure 1: Overview of Forward Mooring Station and concerned line

Figure 2 below shows what may be considered as a typical snap back zone for a line under tension in the configuration shown such that the position of both the relay man and the Officer in Charge may be considered as clear of the snap back zones in the event that the line parted.

Remember! "No job is so important or urgent that we cannot take the time to do it SAFELY"

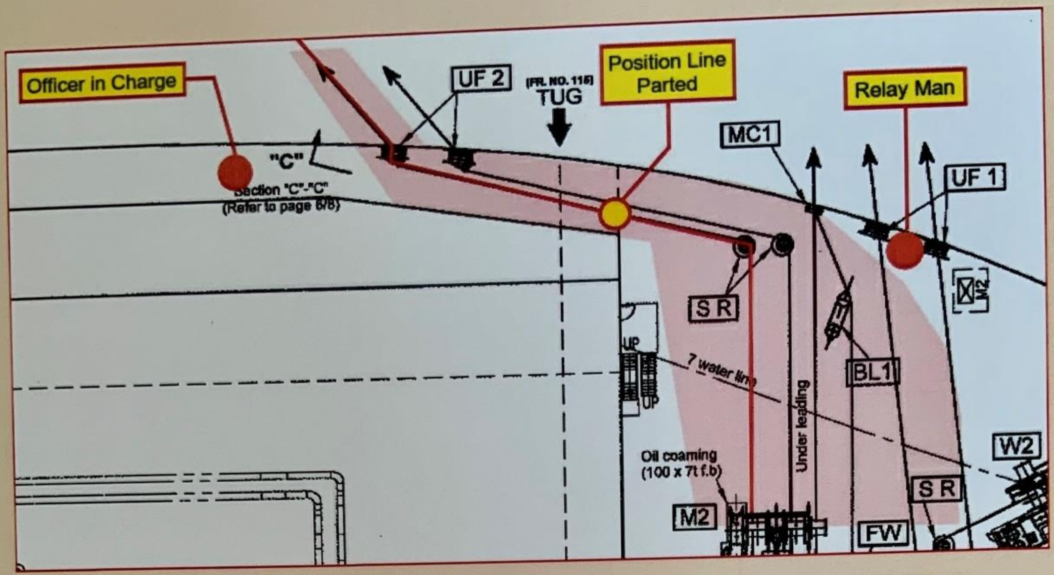


Figure 2: Typical Snap Back Zone Assessment

The line had an MBL of around 137 tonnes but was reported to have parted with only around 28 tonnes of tension load. In this instance it is thought that, because of the multiple changes in direction of the line, the line being secured to the shore hook and the energy contained in the more elastic Euroflex mooring tail, when the line parted it caused the parted end of the line to accelerate aft as displayed in Figure 3 at a rate of around 200 metres per second striking and very seriously injuring the Officer in Charge.

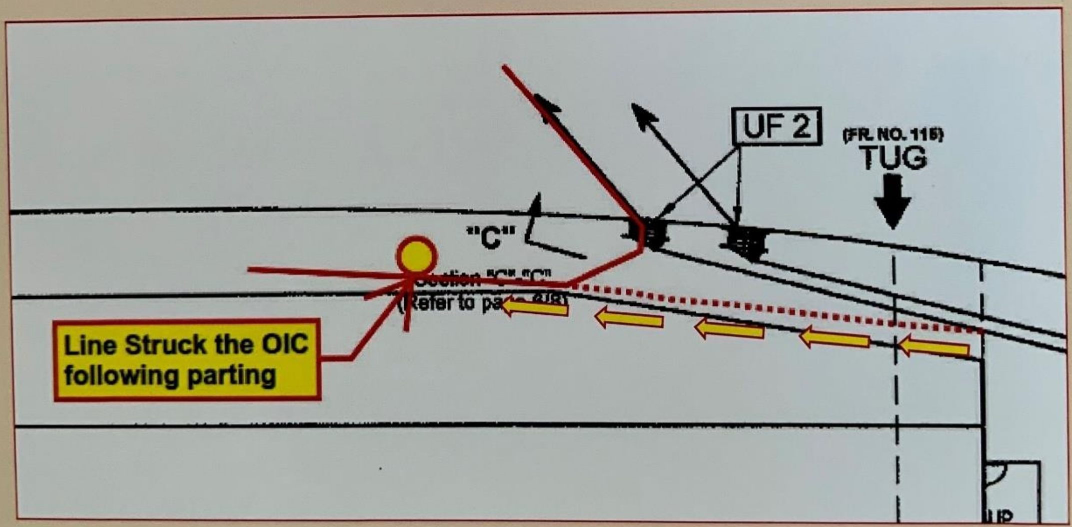


Figure 3: Trajectory of the parted end of the Mooring Line

It is estimated that the Officer in Charge would need to stand in excess of 6 metres aft of the fair lead in order to avoid the potential snap back zone of the line.

Remember! "No job is so important or urgent that we cannot take the time to do it SAFELY"

Immediate Actions required by Vessels

1. Confirm receipt of this Safety Alert to [redacted] and [redacted]

2. The Safety Alert MUST be discussed with all ship's crew at the next HSEQ Meeting or at a specially convened meeting with all crew prior to the next mooring evolution, whichever occurs first. During the meeting, the dangers associated with mooring operations should be re-highlighted as well as the necessity for all ship's crew involved in mooring operations to remain vigilant and aware of the operation at all times. On completion of the meeting, notification should be sent to the above email addresses.

3. Individual ship's MUST assess their mooring decks for the typical configuration of the springs considering the dangers associated with the long aft-running lead inside of the bulwark as depicted in the Figures above. It should be noted that not only forward springs should be assessed but the leads of all of the lines, for and aft, where similar layouts/ leads may arise.

4. Where a vessel has a long lead running aft along the deck such as in the displayed in the above figures, No person is permitted to stand aft of the fairlead in the position shown in Figure 1 whilst the line is under tension. The area should be cordoned off back to a distance of 10 metres.

5. In the event that the springs are run in the same or similar configuration, the Officer in Charge must be stationed on the Trunk Deck as shown in Figure 4 below. This should permit sufficient visibility of the shore side hook and the winch controller such that the operation can be controlled effectively. In the event that the shore hook cannot be viewed from this position, then vessels are required to ensure that the tension on the line can be viewed sufficiently by the use of a further relay man positioned in a safe location well aft of the fairlead.

6. The Safety Alert should be used to reassess the snap back zones of the vessel and vessel diagrams should be amended accordingly.

7. The contents of the Safety Alert should feature as part of JHAs and TBTs for forthcoming mooring operations.

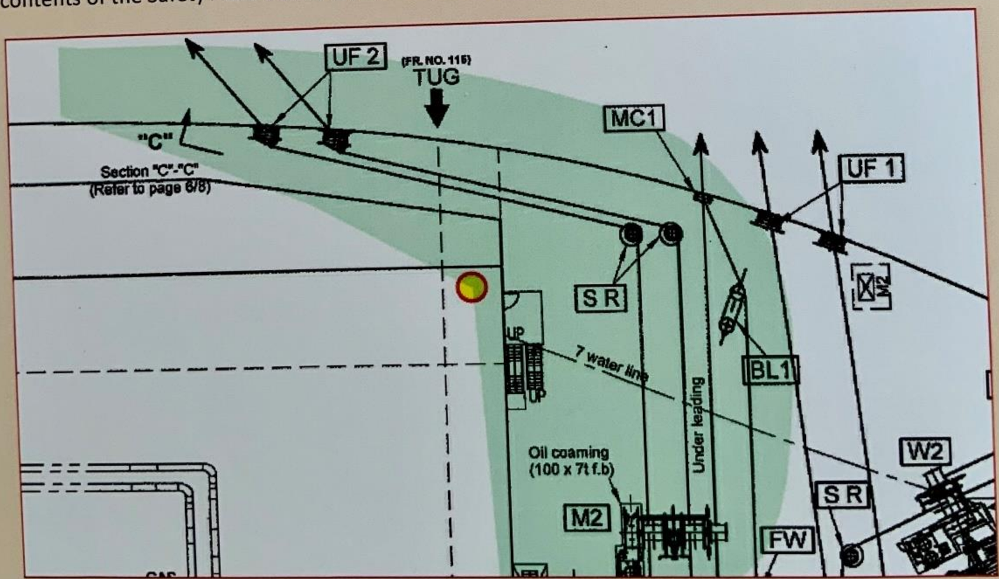


Figure 4: Location for the Officer in Charge – effective field of vision should be as indicated

Remember! "No job is so important or urgent that we cannot take the time to do it SAFELY"

Appendix 3. Safety Alert 22 June 2015 Mooring line parted while alongside berth. The author has anonymized the paper document prior to scanning and attaching.

Safety Alert

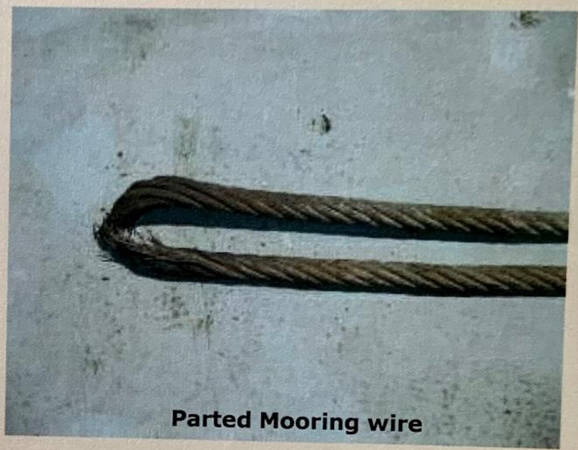
Date of incident	**22nd June 2015**
Subject/Topic	**Mooring line parted while alongside berth**

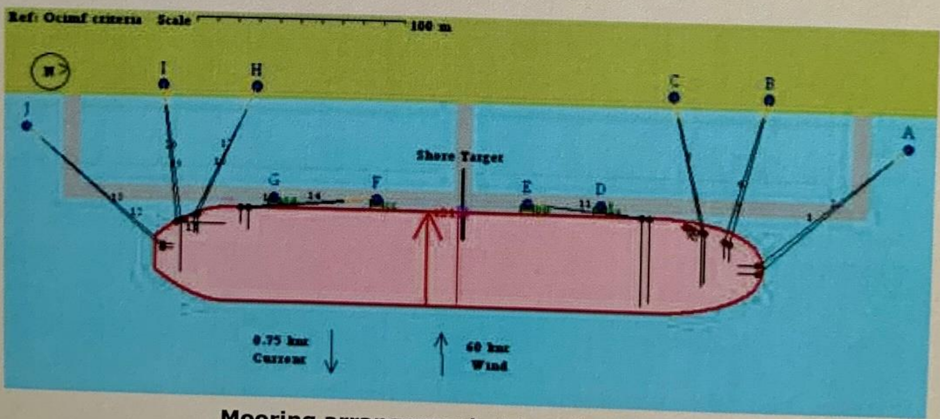
Purpose

The aim of this Safety Alert is to highlight a recent mooring incident which occurred on a [redacted] operated vessel. It should be noted that the actual incident is still under investigation and once concluded, will be available to the public however the below information is provided solely to precaution against safety until the full investigation is concluded and released to the public.

Summary:

The vessel was berthed port-side alongside and safely moored to the Terminal. The cargo discharge operation was in progress. The mooring load monitor was continuously monitored. Since the tension was increasing on the mooring lines due to increasing tide and vessel light condition, the duty crew was sent to slack/adjust the headlines. While slacking the outboard head line, the inboard headline came under tension and parted. The crew members were clear of the snap back zone which prevented a potential personal injury.
The discharge operation was subsequently suspended and the mooring wire was replaced with spare mooring wire onboard.


Parted Mooring wire



Mooring arrangement at terminal

Remember! "No job is so important or urgent that we cannot take the time to do it SAFELY

Appendix 4. Safety Alert 11 April 2016 Wrist injury during greasing of mooring wire. The author has anonymized the paper document prior to scanning and attaching.

Safety Alert

Date of incident	**11th April 2016**
Subject/Topic	**Wrist injury during Greasing of Mooring Wire (LTI)**

This is the notification of the first LTI on a [redacted]essel in 2016.

Incident overview:

- Vessel was at sea on a loaded passage. Job was planned to renew the forward spring mooring wire followed by greasing.
- Manual greasing of this new wire commenced as planned and continued safely till the afternoon tea break. Vessel was using environmentally friendly grease, which was found to be sticky. As a result, the pneumatic greasing pump was unable to create suction. Vessel's attempts to rectify the pump failed and a decision was made to grease the wire manually. Job scope was discussed with all concerned personnel during a tool box talk although there was no formal JHA made for this job.
- AB was assigned to manually grease the wire. He positioned himself in between the two winch drums.
- A wire sling that was used as a restraining wire to enable neat stowage on the drum parted causing a jerk on the mooring wire.
- Residual energy from this jerk transferred to the AB hitting him on the chest and causing a twist in his right wrist.
- AB was administered First aid and advice sought from First Response.
- Upon berthing, the AB was sent ashore for medical attention. He was diagnosed with "Distal Radius Fracture" and was declared 'unfit for duty'.

With immediate effect please note the following:

1. All jobs related to mooring, greasing and such that are non-routine must have a formal risk assessment in place.
2. Manual greasing of wires is forbidden. Vessels are required to use the pneumatic greasing pumps with the appropriate grease. Please contact your Vessel Manager if the greasing pump is not operational.
3. Proper positioning of task is important. When assigning jobs, carrying out 'Take 5' and 'Tool Box Talks' and this aspect should be discussed with the relevant personnel.
4. All persons carrying out a job should be watching each other and should immediately "Stop an Unsafe Act" (standing in the 'line of fire' in this instance) before someone gets injured. This is an Operational Leadership commitment as well as an expectation.

A detailed investigation is in progress and the outcome will be shared with all vessels in order to take home lessons learned and follow up actions.

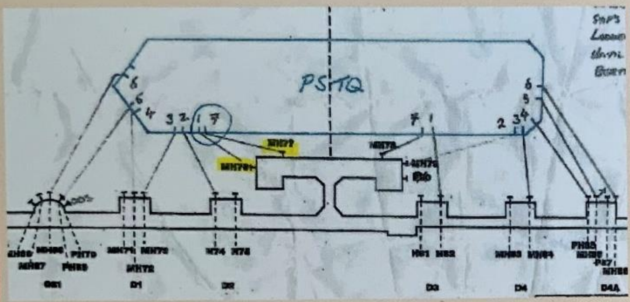
Remember! "No job is so important or urgent that we cannot take the time to do it SAFELY"

Appendix 5. Safety Alert 7 August 2017 Personnel near miss during mooring. The author has anonymized the paper document prior to scanning and attaching.

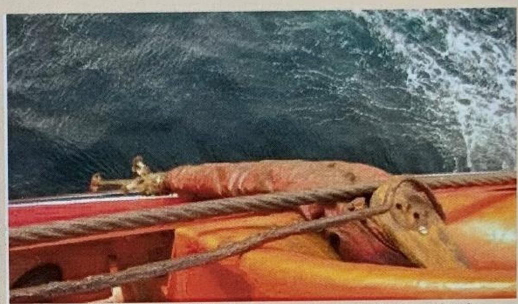
Safety Alert

Date of incident	**07 August 2017**
Subject/Topic	**Personnel Near Miss during Mooring**

During mooring operation in [redacted] at vessel fore station, forward spring line was tight and going close to the ship side. This created a narrow gap between the forward spring line and the ship side. When aft wards spring line was lowered to mooring boat, the shackle was stuck between fairlead and spring wire due to the narrow gap. A hook was then used for pulling the link passed the narrow area (Picture 2) while letting a slack on the mooring winch. When the link passed, the crew member was dragged towards the railings. This could have resulted in a potential injury to crewmember or to the personnel on the mooring boat However there was a small slack on the winch so the crewmember managed to hold on to the hook, released it and took it on deck again.



Picture 1: Mooring Plan



Picture 2: Hook used to pull the link

Picture 3: Crew handling the hook

Direct Cause: Incorrect use of Equipment / Tool
Using the "hook" for purpose for which it was not intended
Using inherently hazardous method

Root Cause: Inadequate Leadership
The officer failed to clearly communicate with the rest of the mooring crew. The crew acted without thinking of the consequences when the link was freed. None of the human biases were considered during the work: Control, Expectation, Efficiency and Familiarity Biases.

Follow up actions
- Discuss Safety Alert during HSEQ meeting and record summary of actions done in HSEQ meeting minutes. Emphasize *situational awareness* that when a situation occur that is not planned for; Take 5 to THINK what may go wrong.
- Update existing JHA for Mooring Operations specific for your vessel. Review and Discuss with ship team.
- Review [redacted]**afety SPOTLIGHT Publication No.2 Mooring Safety** and adapt the "Safe Actions" stated in the spotlight if applicable.

Remember! "No job is so important or urgent that we cannot take the time to do it SAFELY"

Appendix 6. Monthly inspection and lubrication of mooring equipment work description. The author has anonymized the paper document prior to scanning and attaching.

Printed on: 04-05-2019

Standard Job Report

Ship Name: [redacted]
System: SHIP'S EQUIPMENT
Machinery: Winch #1, Mooring
Average Operation Time: 0
Specification Work Category: Lubrication job

Total Hours: 0

JOB TITLE: Winch #1, Mooring >Lubrication and inspecti
JSI: 45
Job No.: 3600013442
Subject Index Term: 4 SHIP EQUIPMENT*Y_SHUTTLE MOP JOBS
Interval: 1 MONTHS
Priority: C
Grace Allowed: 30 Days
Current Run Hour Clock: 0 Hrs
Job Status: Active
Last Date Done: 24-04-2019
Tentative Due Date: 24-05-2019

PREDECESSORS

JOB DESCRIPTION

Winch #1, Mooring >Lubrication and inspecti
WIN-7000.06 - Lubricate and inspect winches/windlasses/wire/tail/links

THIS JOB APPLIES TO ALL WINCHES

FINDINGS MUST REFLECT EACH EQUIPMENT

Lubrication and inspection of winches / windlasses:

Although the responsibility of supervising carrying out the work is by the Chief Officer, the Chief Engineer and or First Engineer are to check and ensure that all lubrication points are clear and bearings properly greased..

LUBRICATION

1) Check that grease nipples and lubrication pipes are free.
2) Operate the machine while the greasing takes place.
3) Pay particular attention to the sleeve bearings on the wire drums, wear off these will cause difficulties engaging the clutch. Renewal entails removing the drum from the shaft.

NOTE:
1) Shaft to be rotated with drums disengaged during lubrication of drum bearings, bearing blocks, step bearings and gear wheels.
2) During frequent use, lubrication must be increased.
3) Teeth on open gears should be coated with open gear lubricant.

MOORING TAIL

1) Inspect mooring tail in full length for wear and tear

MOORING LINK

1) Inspect mooring link

WINCH BRAKE INSPECTION

1) Keep brake linings clean and protected for effective use. Ensure brakes are "on" when winches are not in use to safeguard brake drum surfaces.
2) Maintain brake linkage pins and associated equipment in good working order at all times by effective greasing..
3) Adjust the brake support pins and associated linkages in accordance with the manufacturers recommendations at regular intervals.

WIRE INSPECTION AND LUBRICATION.

1) Inspect the working end of the wire and lubricate adequate length as necessary giving detailed attention to areas around the eye of the wire.
Open an inspection cover located at the bottom side of the casing and drain any water accumulated inside.

Check operation of Limit Switch.
Mooring Winch Brake Lining Check
Check the thickness of the brake lining.
Adjust the brakes if necessary.

Appendix 7. Every 3rd month routine check of mooring equipment work description. The author has anonymized the paper document prior to scanning and attaching.

Standard Job Report Printed on: 04-05-2019

Ship Name [redacted]
System: SHIP'S EQUIPMENT
Machinery: Winch #1, Mooring
Average Operation Time: 0 **Total Hours:** 0
Specification Work Category: Routine Maintenance

JOB TITLE: Winch #1, Mooring >Winch / windlass routine **JSI:** 46 **Job No.:** 3600013443
Subject Index Term: Windlass And Winch*MOORING SYSTEM
Interval: 3 MONTHS **Priority:** C **Grace Allowed:** 30 Days
Current Run Hour Clock: 0 Hrs
Job Status: Active **Last Date Done:** 21-03-2019 **Tentative Due Date:** 21-06-2019

PREDECESSORS

JOB DESCRIPTION

Winch #1, Mooring >Winch / windlass routine
WIN-0000.05 - Winch / windlass routine checks

Winch / windlass routine checks:

1) Check all pipes for leakage or damage.
2) Check all pipe clamps for security & packing if fitted.
3) Check that all valves are in good working order.
4) Check valve packing for leaks.
5) Check and clean filters as necessary.
6) Check lube oil for water contamination, if contaminated with water, drain the water and oil, trace and repair the cause of the contamination and fill with fresh oil.
7) Check fittings for proper operation, check also security of foundation.
8) Check bearing cover bolts for corrosion, renew if necessary.
9) Check following: brake collar, brake lining, spindle male/female portions, brake adjustment and brake securing arrangements.
10) Rectify, if posible, any deficiencies found. Otherwise record for future action.
11) Measure and record the brake lining thickness. Renew the brake lining if worn beyond the acceptable limits.
12) Inspect Mooring Wire Shackles, look for cracks, excessive wear and damage. Maintain the locking pin in such a condition that the pin easily can be removed if required. The shackles should be dismantled every three months.
13) Inspect mooring wire every 6 months if there are no broken wires. If any wire has broken, inspections shall be carried out more frequently. The condition of the mooring wire is to be reported at each inspection.

VESSEL SPECIFIC DESCRIPTION

REQUIRED MATERIAL:

Appendix 8. Every 6th month greasing, and inspection of mooring lines and shackles work description. The author has anonymized the paper document prior to scanning and attaching.

Printed on: 04-05-2019

Standard Job Report

Ship Name: [redacted]
System: SHIP'S EQUIPMENT
Machinery: Winch #1, Mooring
Average Operation Time: 0
Specification Work Category: Lubrication job

Total Hours: 0

JOB TITLE: Winch #1, Mooring >Grease and inspect moori
JSI: 47
Job No.: 3600013444
Subject Index Term: 4 SHIP EQUIPMENT*Y_SHUTTLE MOP JOBS
Interval: 6 MONTHS
Priority: C
Grace Allowed: 30 Days
Current Run Hour Clock: 0 Hrs
Tentative Due Date: 21-05-2019
Job Status: Active
Last Date Done: 21-11-2018

PREDECESSORS

JOB DESCRIPTION

Winch #1, Mooring >Grease and inspect moori
LUB-7000.04 - Grease and inspect mooring wires & shackles

Grease and inspect mooring wires:

1) Inspect the mooring wire.

- Pay specific attention to the eyes, which is shackled to the nylon tails, as the shackle tends to increase wear on the wire at this point.
- All splices must be checked for deterioration. Any eye spliced on a mooring wire shall consist of at least five full tucks and two half tucks against the lay. The splice must include at least one lock.
- During the inspection look for kinking, crushing, crippling, etc, as this can reduce the wire strength by over 30%.
- If "dry" or darkened patches are observed, check the depth and degree of corrosion. An effective way to do this is to place the wire on a solid surface and strike it with a hammer. This will cause the rust to fall away and part the weakened strands, exposing the severity of the corrosion.
- Additionally, the wire may be opened up with a Marlin spike to inspect the rope heart. Care must be taken not to damage it in doing so. If the heart looks dry and powdery then this indicates dry rot and, depending on the degree, the wire should be either lubricated or discarded. If broken wires are found then, if possible, it must be ascertained whether this was caused by mechanical wear or corrosion.

2) The mooring wires to be cleaned and re-greased if necessary.
Prior to lubrication, inspect the entire wire by physically removing the whole wire from the drum (preferably by transferring the wire to another stowage drum). Investigations have shown that deterioration of the wires can occur, undetected, on the bottom layers, especially when a wire has seen some service and has been turned "end for end".

3) Inspect Mooring Wire Shackles
- Look for cracks, excessive wear and damage.
- Maintain the looking pin in such a condition that the pin easily can be removed if required.

VESSEL SPECIFIC DESCRIPTION

REQUIRED MATERIAL:

Appendix 9. Every 12th month break test of mooring winches work description. The author has anonymized the paper document prior to scanning and attaching.

Printed on: 04-05-2019

Standard Job Report

Ship Name: [redacted]
System: SHIP'S EQUIPMENT
Machinery: Winch #1, Mooring
Average Operation Time: 0
Specification Work Category: Test job

Total Hours: 0

JOB TITLE: Winch #1, Mooring >Main brake test/ Inspection and brake lining check
JSI: 49
Job No.: 3600013446
Subject Index Term: Windlass And Winch*MOORING SYSTEM
Interval: 12 MONTHS
Priority: C
Grace Allowed: 30 Days
Current Run Hour Clock: 0 Hrs
Last Date Done: 20-09-2018
Tentative Due Date: 20-09-2019
Job Status: Active

PREDECESSORS

JOB DESCRIPTION

Winch #1, Mooring >Main brake test/ Inspection and brake lining check
WIN-0000.07 - Main brake test/ Inspection and brake lining check

Main brake test for winch and inspection:

Mooring winch brake is to be tested with test equipment annually and also after major overhaul, change of brake lining or modifications to the mooring winches.

Inspect brake:
Refer to the manufacturer's special instructions for further guidelines.

INSPECTION OF THE BRAKE ASSEMBLY:

1) Before inspection, ensure that the equipment is secure. If the brake requires adjustment this should be carried out as the manufacturer advises.
2) Calibrated pressure gauge is to be used for brake test hydraulic tool. Each mooring winch brake MUST be tested to ensure that it hold at 60% of the MBL of the "originally designed" mooring wire (as was at the time of delivery). While occasionally during the replacement of wire, the MBL of slightly higher MBL might have been supplied, however the winch brake should be still set to render at 60% MBL of "originally designed" rope.
3) Inspect the brake lining and gears.
4) Loosen the brake and check entire section of the band for oil impregnation, deterioration, abrasion, cuts. Condition of counter sunk bolts. Measure the thickness of the band and check for any appreciable wear on the band which requires replacement. Check bottom support bolt if correctly position to support the brake.
5) Crack Test (NDT) to be carried out for the forward part of winch brake spindle.
6) Ensure all the mooring winches are set to render at same load (within a very small range and once renders should shed only enough load to bring the line tension back to a safe level).

TESTING EQUIPMENT

BRACKET:
1) The bracket is secured to the drum of the winch by means bolts fitted through holes provided in drum flange.

HYDRAULIC JACK WITH PRESSURE GAUGE
2) Foundation to be placed under the hydraulic jack for the purpose of distibuting the load into the deck structure.

WINCH BRAKE WHEEL CLAMP & TORQUE WRENCH
3) Required for measuring and recording the force exerted on the winch brake wheel to achieve the brake rendering point above the "brake holding capacity". (Refer to MOMS for further details).

PROCEDURE:

Carry out this test using a hydraulic jack against a bolt located in a hole on the brake drum casing. The load to be applied will depend upon the ratio between the distance from the centre of the main drive shaft of the bolt and the brake band and can be calculated on the basis of simple levers.

1. Individually, in line with recommendations in the OCIMF Mooring Equipment Guidelines, 2nd Edition, Chapter 7.5.5.
2. Each mooring winch brake shall normally be tested to ensure that it holds at 60% of the MBL of the mooring wire rope used.
3. Additionally, test pressure of the hydraulic jack is increased sufficiently to check the rendering point of the brake.
4. Ensure the rendering point (the load at which the brake slips or renders itself) is always less than 80% of the MBL of the wire

rope in use. Make suitable adjustments if necessary, and consult the ship team as, and if required.
5. Maintain records of the date of such tests as well as the Brake Holding Capacity and Rendering Point.

Replace winch and / or windlass brake linings:

- If after testing the brake holding power it is found to have reduced from the normal requirement, even after ensuring linkages are free, brake drum has been de-scaled and the incremental device remains properly adjusted.
- If the thickness of the brake lining is reduced to below the manufacturers permissible limit.
- If brake linings are contaminated with oil or grease.
- Change both upper and lower linings at the same time.
- When brake linings are changed out, the brake band drum must be de-scaled to remove any rust and scale. However, check the diameter of the brake drum, after de-scaling to ensure a proper match with the brake band. It may be necessary to either build up the drum to its proper size.

VESSEL SPECIFIC DESCRIPTION

REQUIRED MATERIAL:

Appendix 10. Every 18th month replace mooring line tails work description. The author has anonymized the paper document prior to scanning and attaching.

Standard Job Report Printed on: 04-05-2019

Ship Name: [redacted]
System: SHIP'S EQUIPMENT
Machinery: Winch #1, Mooring
Average Operation Time: 0 **Total Hours:** 0
Specification Work Category: Routine Maintenance

JOB TITLE: Winch #1, Mooring >Replace Mooring Tail. **JSI:** 58 **Job No.:** 49100001489
Subject Index Term: Windlass And Winch*MOORING SYSTEM
Interval: 18 MONTHS **Priority:** C **Grace Allowed:** 30 Days
Current Run Hour Clock: 0 Hrs
Job Status: Active **Last Date Done:** 10-10-2017 **Tentative Due Date:** 10-04-2019

PREDECESSORS

JOB DESCRIPTION

Winch #1, Mooring >Replace Mooring Tail.
WIN-0000.19 - Replace mooring tails

Replace mooring tails.

Mooring tails should be replace at 18 month interval unless experience and / or inspection indicates a shorter period is warranted.

This is in reference to OCIMF Mooring Equipment Guidelines.

VESSEL SPECIFIC DESCRIPTION

REQUIRED MATERIAL:

Appendix 11. Every 30^{th} month turn mooring line wire end for end work description. The author has anonymized the paper document prior to scanning and attaching.

Standard Job Report Printed on: 04-05-2019

Ship Name: [redacted]
System: SHIP'S EQUIPMENT
Machinery: Winch #1, Mooring
Average Operation Time: 0
Total Hours: 0
Specification Work Category: Safety

JOB TITLE: Winch #1, Mooring >End-for-end turn # 1 **JSI:** 52
Job No.: 3600013449
Subject Index Term: Windlass And Winch*MOORING SYSTEM
Interval: 30 MONTHS
Priority: C
Grace Allowed: 30 Days
Current Run Hour Clock: 0 Hrs
Job Status: Active
Last Date Done: 07-12-2016
Tentative Due Date: 07-06-2019

PREDECESSORS

JOB DESCRIPTION

Winch #1, Mooring >End-for-end turn # 1
WIN-0000.10 - End-for-end turn of Mooring wire # 1

Steel Wire Moorings no: 1

_ Steel wire mooring ropes are of standard size and of varying lengths. The intention is to supply vessels with 305 metre wires only where practical. These can then be cropped back to 250 metre working lengths as the ends become worn out, thus effectively extending the working life of the wire.

_ The recommended frequency of examination is once every 6 months if there are no broken wires and more frequently if any wire has broken. Inspections shall be carried out prior each use.

_ From time to time, lubricate the entire wire using an approved medium, such as Nevamelt. This will prevent rusting, which can reduce the strength of the wire in a very short time.

_ Prior to lubrication, inspect the entire wire by physically removing the whole wire from the drum (preferably by transferring the wire to another stowage drum). Investigations have shown that deterioration of the wires can occur, undetected, on the bottom layers, especially when a wire has seen some service and has been turned "end for end". There are company stock pneumatic grease machines (two per team) that are to be utilized by vessels on a rotational basis, and coordinated through the Ship Team.

_ Regular visual inspection is vital, particularly around the eyes, which are shackled to nylon tails, as the shackle tends to increase wear on the wire at this point. All splices must be checked at this time for deterioration.

_ During inspection look for kinking, crushing, crippling, etc as this can reduce the wire strength by over 30%.

_ If "dry" or darkened patches are observed, check the depth and degree of corrosion. An effective way to do this is to place the wire on a solid surface and strike it with a hammer. This will cause the rust to fall away and part the weakened strands, exposing the severity of the corrosion.

_ Additionally, the wire may be opened up with a Marlin spike to inspect the rope heart. Care must be taken not to damage it in doing so. If the heart looks dry and powdery then this indicates dry rot and, depending on the degree, the wire should be either lubricated or discarded. If broken wires are found then, if possible, it must be ascertained whether this was caused by mechanical wear or corrosion.

_ Turn wires end-for-end every thirty months.

_ The wire is to be changed out when:
Ø Within any wire lay length of the wire rope, the number of broken wires exceeds 10% of the number of wires in the rope.
Ø Within any length of eight diameters of the wire rope, the number of broken wires exceeds 10% of the number of wires in the rope, or
Ø There has been deterioration in the effective diameter of the wire, which is easily apparent. As new wires are normally 5% oversize, 5% deterioration from the nominal size may be considered as reason for a change out.
Ø Signs of general deterioration become visible, which affects its strength.
Ø If an older wire cannot be fitted with a mechanical splice.

_ Mooring wires may be provided with either manual or mechanically spliced soft eyes. If areas near the eye are found to have deteriorated, this can be cut off along with a sufficient length of wire and a suitable eye spliced manually, provided that the length of wire does not reduce to less than 250m.

_ Any eye spliced on a mooring wire shall consist of at least five full tucks and two half tucks and include at least one lock. Splicing against the lay is preferred to splicing with the lay.