

Analysis of The Use and Maintenance of Mooring Ropes To Support Safety When Ships Are Moored

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Abstract.

This research is motivated by the high risk of accidents in ship berthing operations due to mooring line failures that still frequently occur in ports. The purpose of this study is to analyze the use and maintenance of mooring lines in supporting ship safety when berthing. This study uses a descriptive qualitative approach. The study population is all crew members involved in mooring and unmooring activities on the Mv. Tanto Sentosa, while the sample was selected using a purposive sampling technique based on direct involvement in berthing operations. The research instrument is the researcher himself, with data collection techniques through observation, interviews, and documentation. Data analysis was carried out using the interactive model of Miles, Huberman, and Saldaña through data reduction, data presentation, and drawing conclusions. The results of the study indicate that the use of mooring lines is in accordance with the function and Ocimf Meg3/Meg4 standards, and the equipment is in good condition based on CCS inspections. Maintenance is carried out routinely through rinsing, storage, and periodic inspections. However, weaknesses are still found in the documentation aspect, namely the absence of a Line Management Plan (LMP). The conclusion of this study shows that the use and maintenance of mooring lines has been running well and supports ship safety, but improvements are needed in the maintenance documentation system to comply with IMO standards.

Keywords: Maintenance, Mooring Line, Mooring Operation, Qualitative Research and Ship Safety.

I. INTRODUCTION

Ship safety during mooring and unmooring is a critical issue in the modern shipping industry due to the high risk of accidents during mooring and unmooring. Increasing global port activity demands the use of safe, strong, and well-maintained mooring lines to prevent ship damage and worker injuries. Recent research shows that mooring line failure remains a leading cause of port accidents (Lee *et al.*, 2021; Li *et al.*, 2024).

In Indonesia, increased maritime transportation activity has increased the risk of accidents due to broken mooring lines. One such incident occurred at Bakauheni Port in 2023, resulting in a worker being injured by a broken mooring line. International and national regulations emphasize the importance of mooring line inspection and maintenance, but implementation in the field remains suboptimal (Hsu & Kao, 2021; Voliansky *et al.*, 2025).

Various previous studies have confirmed that mooring line condition, material quality, and operator competence significantly influence vessel safety during berthing. These studies generally discuss the technical analysis of mooring systems, rope tension distribution, and the influence of human and environmental factors on vessel operational safety (Lee *et al.*, 2021; Paulauskas & Paulauskas, 2025).

However, previous research remains limited by its focus on technical aspects and simulations of mooring systems. Studies on the use and maintenance of mooring lines on ships, particularly on merchant vessels in Indonesia, are relatively limited. Furthermore, crew monitoring of line conditions during berthing operations has not been thoroughly analyzed (Mwange *et al.*, 2024; Voliansky *et al.*, 2025).

Based on these conditions, there is still a research gap regarding the relationship between the use, supervision, and maintenance of mooring lines and ship safety during berthing. Researchers' experience with the breakage of a spring line at Gorontalo Port shows that negligent supervision can increase the risk of accidents and hinder the berthing process. Therefore, this study focuses on analyzing the effective use and maintenance of mooring lines to support ship operational safety.

This study aims to analyze the effective use of mooring lines and proper maintenance procedures to maintain their performance and lifespan. This research is important because ship operational safety is significantly influenced by the condition and handling of mooring lines. The novelty of this study lies in the integration of analysis of operational use and maintenance of mooring lines within the context of maritime safety.

II. METHODS

This study uses a qualitative approach with descriptive methods to understand the use and maintenance of mooring lines to support ship safety while berthing. This approach was chosen because it can provide an in-depth description of operational phenomena based on real-world conditions through direct observation, interviews, and documentation. Qualitative research positions the researcher as the primary instrument in collecting and interpreting data, allowing the results to comprehensively and contextually describe the operational conditions of ships (Creswell & Creswell, 2023; Sugiyono, 2022; Emzir, 2021).

The population of this study was all crew members involved in mooring and unmooring activities, particularly deck officers, helmsman, and crew members responsible for the use and maintenance of mooring lines. The sampling technique used purposive sampling, selecting informants based on their work experience, direct involvement in the ship's mooring process, and understanding of mooring line operational procedures, resulting in more relevant and in-depth data in line with the research objectives (Sugiyono, 2022; Creswell & Poth, 2023).

The primary instrument in this research was the researcher (human instrument) who directly conducted observations, interviews, and data interpretation in the field. Data collection techniques included observations of mooring line operations during berthing and unberthing, in-depth interviews with ship officers and crew, and documentation in the form of photographs, videos, and ship operational documents related to mooring line use and maintenance. These techniques were used to obtain complete, in-depth data that reflected actual conditions in the field (Sugiyono, 2022; Emzir, 2021; Creswell & Creswell, 2023).

The data analysis technique used the interactive analysis model of Miles, Huberman, and Saldaña, which includes data collection, data reduction, data presentation, conclusion drawing, and verification. Analysis was carried out continuously throughout the research process by selecting and simplifying relevant data, then presenting it in narrative form to systematically understand the relationships between the data. The final stage was verification to obtain valid and objective conclusions based on the results of observations, interviews, and research documentation (Miles *et al.*, 2020; Sugiyono, 2022).

The research procedure was carried out systematically through several stages, namely preliminary studies, field research, data analysis, and preparation of the research report. The initial stage involved identifying the problem and reviewing literature related to ship operational safety and the use and maintenance of mooring lines. Subsequently, field research was conducted during sea practice through direct observation, interviews, and documentation of ship operational activities. The data obtained were then analyzed using an interactive analysis model and interpreted based on theory and previous research, resulting in conclusions and recommendations related to improving ship safety at port while berthing.

III. RESULTS AND DISCUSSION

Data Presentation

Based on the results of research during sailing practice on the MV. TANTO SENTOSA, it is known that the procedures for the use and maintenance of mooring lines have referred to the provisions in the Mooring Equipment Guidelines (MEG3) published by OCIMF. Mooring line maintenance is considered very important to maintain the safety of the ship's crew and operational security during loading and unloading activities at the port. This study focuses on the use and maintenance of synthetic nylon mooring lines used on board the ship. Research data were obtained through direct observation of the condition of the mooring lines and interviews with the ship's crew regarding maintenance practices applied during operations.

Table 1 Condition of Mooring Operation Equipment

Observation Items	Findings on the Ship	Notes
Mooring line attached to the windlass drum	One roll of mooring rope is 200 meters long and is in good condition.	No broken rope loops were found.
Spare mooring lines stored in the forecandle store	The spare rope is in good condition and has adequate length.	No signs of damage were found. The rope is ready to use whenever needed.
Windlass machine	Windlass machine in prime condition	The power of the windlass engine is still reliable and indicates no signs of damage or leaks in the hydraulic pump.
Bollard	Bollard in good condition	There is no excessive corrosion on the bollards. The bollard plates are still thick enough to

		withstand extreme tensile forces during mooring operations.
Chocker	Chocker in good condition	There is no excessive corrosion on the choker
Fairleads	Fairleads in good condition	No excessive corrosion was found on the fairleads.
Roller	Roller in good condition	The bearings on the rollers are always greased every 3 months so that the rollers can still rotate smoothly during mooring operations.



Fig 1. Surveyors from the China Classification Society conducted an inspection of the condition of the mooring lines.

On Monday, June 23, 2025, surveyors from the China Classification Society (CCS) conducted an inspection while the ship was docked at Tanjung Perak Port, Surabaya. The surveyors found the mooring lines on board were in good condition, with no signs of damage.

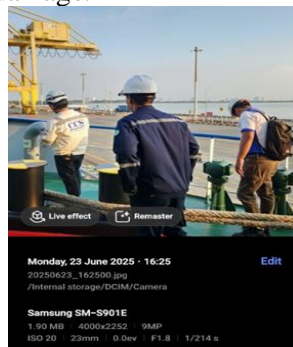


Fig 2. Date of Inspection

When the ship was on its way from Tangkiang to Surabaya, the Chief Officer ordered the bosun and deck crew to clean the forecastle deck including the winch engine, rope drum and also the mooring rope to avoid corrosion and wear on the rope caused by splashes of sea waves.



Picture 3 Deck Crew Cleaning

Observations made by researchers indicate that maintenance practices have been carried out with sufficient discipline and regularity, ensuring that mooring lines and other mooring equipment are always in prime condition and ready for use at any time. This aligns with IMO MSC.1/Circ.1620 (2022) requirements, which require routine inspections of all ship mooring equipment to ensure it is always fit for use and safe for operation (IMO, 2022).

Table 2 Ship Crew Responsibilities & Duties

Ship's crew	Duties and responsibilities
Chief Officer(1st Officer)	Responsible for procuring ropes, planning and

Ship's crew	Duties and responsibilities
	supervising mooring operations and ensuring all mooring equipment is in good condition.
2nd Officer(2nd Officer)	In charge of leading mooring operations at the stern and assisted by 1 helmsman.
3rd Officer(3rd Officer)	In charge of leading mooring operation activities at the bow, assisted by the bosun and cadets.
Bosun	On duty at the Bow with Officer 3 and cadets in the process of installing mooring ropes.
A/B (Helmsman)	Responsible for assisting the second officer in carrying out mooring operations, including operating the winch, throwing the discard line and handling the mooring lines during the mooring process.

Researchers have also conducted short interviews with *Chief Officer, 2nd Officer, 3rd Officers, Bosuns and A/B (Helmsman)* to obtain more detailed information regarding maintenance procedures and the use of mooring lines to support safety when the ship is moored.

Table 3 Crew Interview Results

Ship's crew	No.	Question	Answer
<i>Chief Officer</i>	1	What risks can occur if mooring ropes are not properly maintained?	Risks that can occur include the breaking of mooring lines when the ship is docked due to the reduced elasticity of the hardened rope, then snap-back which can endanger the ship's crew, as well as the shifting of the ship's position from the dock.
	2	How often are mooring lines inspected?	Crew inspections are typically conducted before and after mooring operations. Surveyor inspections are conducted annually when the ship is berthing at Homebase Port (Surabaya).
	3	Apart from mooring lines, what mooring operation equipment must be checked periodically?	Hydraulic pump on winch machine, bearing on roller, bollard and chocker.
<i>2nd Officer</i>	4	What is the procedure for using mooring lines when the ship is docked?	The procedure begins with a call to the engine room to start the winch. Then, all mooring lines are prepared on deck: the headline, sternline, breastline, and spring line. Once the ship begins to approach the dock, the mooring line is thrown ashore, followed by the spring and tross lines, following the chief officer's instructions. The line, which has reached the dock, is then tied to a bollard on the dock. Once attached, the line is carefully pulled using a winch until the ship is docked.
	5	What are the technical indicators used to determine whether a mooring line is still suitable for use or needs to be replaced?	Indicators used include the condition of the rope fibers, the degree of wear, changes in rope diameter, and the presence of broken or hardened fibers. If the damage reaches a certain level and has the potential to reduce the rope's tensile strength, the rope must be replaced immediately to avoid the risk of breaking during mooring operations.
<i>3rd Officer</i>	6	What is the procedure for storing rope? correct mooring so that it does not get damaged quickly?	Mooring lines should be stored dry and neatly rolled up after use. Before storage, mooring lines should be rinsed with fresh water to remove any seawater absorbed into the rope fibers. Storage should be done in a place protected from sunlight, covered with a tarpaulin to avoid seawater splashes, and not exposed to oil or chemicals that can damage the rope fibers.
<i>Bosun</i>	7	In your experience, what is	The biggest risk is the mooring lines breaking

Ship's crew	No.	Question	Answer
		the biggest risk that can occur if mooring lines are not properly maintained?	while the ship is docked. I experienced this when I was on the MV TANTO HANDAL. Strong winds in Makassar Harbor caused the already brittle spring lines to snap. Fortunately, there was still a tross line that held the ship in place before the spring lines could be reattached using spare lines.
A/B (Helmsman)	8	In your opinion, how important is cooperation and communication between crews in mooring operations?	Cooperation and communication between crew members are crucial because mooring operations require concentration and coordination. Each crew member must understand their respective roles, from throwing ropes and operating winches to monitoring the ship's position. Poor coordination can increase the risk of accidents.

Data analysis

The research data was obtained through direct observation and interviews with the crew of the Mv. Tanto Sentosa who were involved in mooring activities, such as the First Officer, Second Officer, Third Officer, Bosun, and Helmsman. The analysis was conducted by comparing the field results with the Mooring Equipment Guidelines (MEG3) standards from OCIMF to determine the suitability of the mooring rope use and maintenance procedures to ship safety standards. The results of the study indicate that the use of mooring ropes on board has been carried out quite well according to the function of each rope to maintain the stability of the ship during berthing and loading and unloading. In addition, mooring rope maintenance is also carried out routinely by the Bosun and deck crew under the supervision of the Chief Officer through inspection of the rope condition, proper storage, and winding the rope on the winch drum to prevent damage to the rope fibers due to load, seawater, and exposure to sunlight. The inspection results from the China Classification Society (CCS) also show that the condition of the mooring rope is still suitable for use and meets applicable safety standards. However, the risk of accidents such as rope breaks and snap-back can still occur if safety procedures are not implemented properly. Therefore, disciplined use, routine maintenance, and crew awareness of work safety are important factors in maintaining the operational safety of the ship when berthing.

IV. DISCUSSION

1. Use of Mooring Ropes on Mv. Tanto Sentosa

Based on the results of research and direct observations conducted by the author during the sea practice on the MV. TANTO SENTOSA, the use of mooring lines on the ship has been carried out in accordance with the applicable functions and procedures. Each type of mooring line functions appropriately according to its role: the head line and stern line restrain the longitudinal movement of the ship, the breast line keeps the ship docked transversely to the port, and the spring line prevents the ship from moving forward or backward. This configuration is in accordance with the standards set by the Oil Companies International Marine Forum (OCIMF, 2018) in the Mooring Equipment Guidelines Fourth Edition (MEG4) which states that the configuration of six types of mooring lines is the minimum requirement to ensure the stability of the ship when moored. (Oil Companies International Marine Forum (OCIMF), 2018)

This finding is in line with Pratama's (2023) research entitled "Analysis of Mooring Line Maintenance for Smooth and Safe mooring operation at MT. Petromax". (Pratama, 2023) concluded that the success of a docking operation is largely determined by the crew's understanding of how to apply each type of mooring line according to its function, where failure to apply the correct configuration can cause the ship to shift from a safe berthing position and endanger all operations at the port. On the Mv. Tanto Sentosa, all crew members involved in the mooring operation have a good understanding of the role of each line as shown by the results of field observations and interviews conducted by the author, so that the mooring operation process at each port of call can take place in an orderly and safe manner.

In addition, Umam (2019) in a paper entitled "Optimizing Mooring Rope Maintenance on KM. Kelimutu" also emphasized that a good mooring rope operating system and procedures must begin long before berthing, including the preparation stage of all mooring equipment to the implementation of rope tying at the port. (Muhammad, 2019) This procedure has been carried out consistently on the Mv. Tanto Sentosa, where before the berthing manuevre process, the Chief Officer gives directions to all crew and ensures that all mooring ropes have been prepared in a ready-to-throw position on the deck. Discipline in implementing this

procedure is one of the key factors that makes every mooring operation on the Mv. Tanto Sentosa run well during the author's sea practice period.

2. Mooring Line Maintenance on the Mv. Tanto Sentosa

The results of the study indicate that mooring line maintenance on the Mv. Tanto Sentosa has been carried out routinely and in a disciplined manner under the direct supervision of the Chief Officer. The maintenance practices carried out include: (1) rinsing the line with fresh water after each use to remove salt content that can accelerate fiber degradation; (2) storing the line in a forecabin store protected from direct sunlight and seawater splashes; (3) carefully rewinding the line on the winch drum to prevent twisting or bending that can weaken the line; and (4) lubricating the roller bearings every three months. All of these practices are in accordance with the provisions stipulated in the OCIMF Effective Mooring (2020) which states that the line must be kept away from chemicals, stored in a well-ventilated area, inspected visually and periodically, and kept from being exposed to excessive heat or friction. (Guidelines For Inspection And Maintenance Of Mooring Equipment Including Lines, 2020).

This good maintenance condition directly affects the operational feasibility of the mooring lines. Mudiyanto and Pamungkas (2019) in a journal entitled "The Importance of Mooring Line Maintenance on the MV. Bali Kuta for Smooth Berthing" published in the Journal of Shipping and Port Applications concluded that "discipline in carrying out mooring line maintenance directly contributes to the smooth and safe process of berthing ships at the Port. (Mudiyanto, 2019) The study found that ships that implement a regular mooring line maintenance schedule experience fewer incidents of line failure than ships whose maintenance is reactive. This reinforces the importance of a proactive maintenance system such as that implemented on the Mv. Tanto Sentosa under the supervision of the Chief Officer.

The use of nylon rope on the Mv. Tanto Sentosa also requires special attention to the influence of the marine environment. In the book "Machinery Maintenance System" it is emphasized that exposure to ultraviolet (UV) rays, sea water, and repeated loads are the three main factors causing degradation of synthetic rope fibers, so that correct storage procedures are a critical component in the ship's deck equipment maintenance system (Hadi Prasutiyon, Erik Sugianto, Frenki Mohamad Felayati, Sutrisno, Semin, 2025) Nylon rope has a fairly high water absorption property; if stored in wet conditions for a long time, the rope will experience a significant decrease in tensile strength. Therefore, the procedure of rinsing with fresh water and drying before storage which is carried out consistently on the Mv. Tanto Sentosa is the right step and is in accordance with these scientific recommendations.

3. Safety Risks and Prevention Efforts in Mooring Operations

Improper use and maintenance of mooring lines can pose serious safety risks. Based on an interview with the Chief Officer of Mv. Tanto Sentosa, these risks include the breaking of the mooring line due to the reduced elasticity of the hardened line, the occurrence of a snap-back phenomenon that endangers the crew, and the shifting of the ship's position from the dock. The snap-back phenomenon is the most critical threat in mooring operations, namely a condition where the line that breaks due to excessive tension will move back at very high speed and kinetic energy so that it can cause serious injury or death. Real-life experience of this risk was conveyed by the Bosun of Mv. Tanto Sentosa, who said that while working on Mv. Tanto Handal, strong winds in Makassar Harbor caused the brittle spring line to break while the ship was docked, and only the tross line remained to hold the ship's position before the spring line could be connected with a spare line.

This is in line with the findings of Effendi (2020) in a study entitled "Mooring Rope Maintenance Efforts to Prevent Accidents While Mooring" which concluded that poor mooring rope maintenance, due to low levels of concern and minimal knowledge possessed by the crew, has been proven to result in the condition of the rope being unsuitable for use and significantly increasing the risk of accidents while mooring (Efendi, 2020). This finding is in contrast to the conditions found on the Mv. Tanto Sentosa, where maintenance was carried out in a disciplined manner so that the mooring rope and all mooring equipment were proven to be in prime condition based on the results of the CCS inspection in June 2025. Thus, consistent maintenance efforts are the most effective and efficient form of safety risk prevention in the context of ship operations at the port.

From the perspective of current international regulations, the maintenance practices carried out on the Mv. Tanto Sentosa are generally in accordance with the provisions of the International Maritime Organization (IMO, 2020) in MSC.1/Circ.1620 concerning Guidelines for Inspection and Maintenance of Mooring Equipment Including Lines, which will be enforced mandatory for all SOLAS vessels as of January 1, 2024. This regulation requires every vessel to carry out routine inspections of all mooring equipment, document the inspection results in a structured Line Management Plan (LMP), and make decisions about rope replacement based on actual physical conditions (Guidelines For Inspection And Maintenance Of Mooring Equipment Including Lines, 2020). An inspection by a China Classification Society (CCS) surveyor on June 23, 2025,

confirmed that the condition of the MV. TANTO SENTOSA's mooring lines still meets applicable international safety standards. However, this study found that the Mv. Tanto Sentosa has not formally prepared a Line Management Plan (LMP) as required, so the maintenance documentation aspect needs to be immediately improved to prevent the ship from being found during a Port State Control Inspection.

Overall, the discussion above shows that the use and maintenance of mooring lines carried out on the Mv. Tanto Sentosa has been running quite well and in accordance with applicable operational standards and international regulations. The use of appropriate lines according to their function, combined with a routine and disciplined maintenance system, has proven to be able to maintain the condition of the mooring lines and all mooring equipment in prime condition, thus supporting safety when the ship is berthed. Improvements that still need to be made are the preparation of a formal Line Management Plan (LMP) as required by the IMO (2020), so that this well-running maintenance system can be documented completely, structured, and can be accounted for by regulations. (Guidelines For Inspection And Maintenance Of Mooring Equipment Including Lines, 2020).

V. CONCLUSION

The results of the study indicate that the use and maintenance of mooring lines on the Mv. Tanto Sentosa have been carried out quite well and in accordance with applicable operational standards and international provisions, especially the Mooring Equipment Guidelines (MEG3 and MEG4) from OCIMF and IMO guidelines regarding the inspection and maintenance of ship mooring equipment. The use of each type of mooring line has been implemented according to its function in maintaining the stability of the ship when moored, while routine maintenance is carried out through periodic inspections, rinsing the lines with fresh water, proper storage, and direct supervision by the Chief Officer. The research findings also show that the discipline of the crew in carrying out mooring operation procedures plays an important role in reducing the risk of work accidents such as rope breaks and snap-back phenomena. In addition, the inspection results from the China Classification Society (CCS) prove that the condition of the mooring lines and mooring support equipment on board is still suitable and safe to use to support the operational safety of the ship when moored.

However, this study still has limitations because it was only conducted on one research object, namely Mv. Tanto Sentosa, so the results of the study cannot be generalized to all types of merchant vessels with different operational characteristics. This study also focuses more on a qualitative approach based on observations and interviews so that it has not yet analyzed technically the tensile strength of the rope or the level of material wear quantitatively. Therefore, further research is recommended to combine qualitative and quantitative approaches through technical testing of mooring rope performance on various types of vessels and port conditions. Practically, this study is expected to be an evaluation material for shipping companies in improving mooring rope maintenance systems, strengthening the work safety culture of ship crews, and preparing a more structured Line Management Plan in accordance with IMO provisions to minimize the risk of accidents during ship berthing activities.

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