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Article

Proper Use of Mooring Lines on Ships to Ensure a Smooth Berthing Process on The MT. Giat Armada 04

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A B S T R A C T

This study aims to analyze the influence of the physical condition of mooring lines and supporting mooring components on the smooth berthing process of MT. GIAT ARMADA BERSAMA 04. The berthing process is a critical operational phase requiring a highly reliable mooring system to ensure the safety of the vessel, cargo, crew, and port facilities. Employing a qualitative descriptive method, data were collected through field observations across 12 berthing operations, structured interviews with deck officers, and document analysis. The findings revealed that the physical deterioration of the spring lines—specifically characterized by a visible diameter reduction, bird-caging, and surface abrasion exceeding the 10% broken strand threshold—contributed to severe operational difficulties. Furthermore, corroded deck fittings increased mechanical friction, leading to ropes jamming in the mooring chocks and significant delays in tension adjustment. Evaluated against the retirement criteria and inspection parameters defined by the OCIMF Mooring Equipment Guidelines (MEG4) and IMO safety mandates, the vessel's mooring components operated below acceptable minimum breaking load (MBL) safety margins. Immediate replacement of degraded lines and the implementation of a strict Line Management Plan (LMP) are imperative to restore operational precision, mitigate occupational hazards, and enhance overall port efficiency.

1. Introduction

Sea transportation operates as the primary conduit of the global logistics network, requiring commercial vessels to maintain absolute structural stability and operational safety across all navigational phases (Kaluza et al., 2010; Syam & Sunusi, 2023). While maritime research frequently emphasizes open-water navigation, the berthing process represents one of the most mechanically demanding operational phases, heavily reliant on the engineering reliability of the ship's mooring system (Yulianto & Atok, 2024). Securing a vessel to a pier against dynamic environmental forces—such as wind, current, and tidal variations—requires a mooring arrangement that operates flawlessly within its engineered safety limits (Pamungkas, 2019).

To guarantee this operational reliability, international regulatory frameworks, specifically the Safety of Life at Sea (SOLAS) Chapter II-1/3-8 and the Oil Companies International Marine Forum's Mooring Equipment Guidelines (OCIMF MEG4), establish strict mandates for the design, inspection, and maintenance of mooring systems. These standards dictate that all mooring equipment must be maintained in a condition suitable for its intended purpose to prevent catastrophic mechanical failures, such as line parting under extreme tension, which has historically resulted in fatal casualties (Detik News, 2020).

Despite the existence of these stringent standards, operational realities often reveal significant compliance gaps. The MT Giat Armada Bersama 04, a tanker vessel executing frequent port-to-port operations, has experienced recurrent berthing delays caused by the physical degradation of its mooring lines and supporting deck equipment. While previous studies have extensively modeled hydrodynamic tensions (Yupiter et al., 2024) or evaluated shipyard mooring hazards (Hardiyono et al., 2022), there remains a distinct research gap concerning the qualitative evaluation of real-time operational degradation of synthetic mooring lines against measurable OCIMF MEG4 parameters during active berthing. Therefore, this study aims to bridge this gap by analyzing the physical condition of the mooring components on the MT Giat Armada Bersama 04, evaluating their compliance with international engineering standards, and determining their direct implications for berthing safety and port efficiency.

2. Literature Riview

2.1 Synthesis of Previous Studies

The academic discourse surrounding mooring operations highlights a strong focus on numerical and hydrodynamic modeling. Yupiter, Mursid, and Trimulyono (2024) conducted a numerical analysis on the motion and tension of Ro-Ro vessel mooring lines, demonstrating that environmental wave loads dictate the tension limits required for a stable spread mooring system. Similarly, Darwis (2024) and Kurniawan (2024) utilized the Boundary Element Method (BEM) to establish that increasing mooring line length and radius effectively reduces localized tension on individual lines, thereby optimizing the structural stability of floating units. While these studies provide critical insights into force distribution, they operate under the assumption of ideal material conditions. Conversely, Widodo, Wahyuni, and Satrio (2024) shifted the focus to operational management, concluding that the rigorous application of a Mooring System Management Plan (MSMP) significantly reduces the risk of line parting. Synthesizing these studies reveals a critical novelty for the present research: while the hydrodynamic forces acting on mooring lines are well-documented, there is a substantial need to empirically analyze how the physical, material degradation of ropes and deck fittings compromises the theoretical force equilibrium and mechanical safety margins during actual berthing operations.

2.2 Engineering Concepts of Mooring Operations

The The berthing process relies on the mechanical interaction between the vessel's mooring lines and the structural deck fittings (e.g., bollards, chocks, and fairleads). From a naval engineering perspective, mooring lines are not static tethers; they are dynamic shock absorbers that must manage continuous load distribution and force equilibrium (American Boating Association, n.d.).

The operational integrity of these lines is defined by several critical mechanical properties:

a. Minimum Breaking Load (MBL) & Working Load Limit (WLL): The MBL is the certified maximum force a new rope can withstand before parting, while the WLL (typically a fraction of the MBL) is the maximum safe operational load.

b. Elasticity and Creep Behavior: Synthetic ropes, particularly polypropylene and nylon, possess high elasticity to absorb kinetic energy. However, under sustained tension, these materials exhibit creep—a slow, progressive, and permanent mechanical elongation that ultimately weakens the fiber structure.
c. Fatigue Resistance and Residual Strength: Continuous cyclic loading and localized abrasion (chafing) against rough deck fittings induce structural fatigue. As the outer strands break or suffer UV degradation, the rope's residual strength decreases rapidly, pushing the operational loads dangerously close to the compromised breaking threshold.

2.3 Characteristics and Functional Types of Mooring Lines

According to the International Maritime Organization (2020), mooring lines are specialized ropes or cables utilized to secure a vessel to a dock, buoy, or another ship, specifically designed to counteract external drifting forces. Functionally, mooring lines are deployed in specific configurations to neutralize different directional forces. Tross lines (head and stern lines) are deployed to restrain lateral displacement, whereas spring lines are positioned diagonally to prevent the vessel from surging forward or moving aft while alongside the berth (American Boating Association, n.d.). Breast lines are frequently added between the tross and spring lines to provide supplementary lateral stability.

The material composition of mooring lines dictates their physical performance and operational longevity. Natural fiber ropes, such as abaca (highly flexible and water-resistant), sisal (vulnerable to moisture), and hemp, were historically prevalent but have largely been superseded by modern alternatives (Indonesia Marine Equipment, 2020).

2.4 Selection Criteria and Maintenance Protocols

Selecting the appropriate mooring line requires a multidimensional assessment of the vessel's operational environment. Boomarine Supplies (2023) identifies several critical selection factors.

To preserve these physical properties, strict maintenance protocols must be executed. Routine visual inspections are mandatory to identify parted strands, internal core damage (bird-caging), or fungal deterioration. Furthermore, lines must be periodically cleaned using fresh water to extract embedded salt crystals and abrasive particulate matter that can internally sever fibers. When not actively deployed, mooring lines must be systematically coiled and stored in well-ventilated, dry compartments shielded from direct solar radiation and chemical exposure.

2.5 Inspection and Retirement Criteria (OCIMF MEG4)

To prevent mechanical failure, OCIMF MEG4 and SOLAS MSC.1/Circ.1620 mandate rigorous inspection protocols. Routine visual inspections must assess quantifiable deterioration indicators, including reductions in rope diameter, the percentage of broken filaments per strand (typically retiring lines if broken strands exceed 10% in any localized area), and the integrity of eye splices. Strict adherence to these retirement criteria is essential to maintain the engineered reliability of the mooring system.

3. Research Methodology

3.1 Research Design and Validation

This study employed a qualitative descriptive methodology to investigate the operational precision of mooring line utilization. To ensure methodological rigor and research transparency, data credibility was established through strict triangulation. Observational data regarding equipment degradation were cross-validated against the vessel's official maintenance logs and the subjective operational experiences detailed in the interview transcripts, minimizing observational bias (Patton, 2020).

3.2 Data Collection Procedures

The field research was conducted aboard the MT Giat Armada Bersama 04 over a continuous 12-month operational period.

a. Observation Procedures: Direct visual inspections and operational monitoring were conducted across 12 specific berthing evolutions. The observation checklist was explicitly designed based on OCIMF

MEG4 visual inspection parameters, focusing on measurable indicators such as surface abrasion, bird-caging, core exposure, and the friction coefficients of the deck chocks.

b. Interview Protocols: Semi-structured interviews were conducted using purposive sampling, targeting the Chief Officer and the Boatswain, as they are directly accountable for the vessel's mooring operations and Line Management Plan (LMP). The interview protocol explored operational constraints, the frequency of equipment failures, and the criteria utilized for determining rope retirement.

3.3 Data Analysis Techniques

Data were processed using the interactive model by Miles, Huberman, and Saldana (2014). During the data condensation phase, the qualitative field findings were systematically interpreted through the lens of engineering standards. For instance, observed structural anomalies in the ropes were directly benchmarked against MEG4 retirement criteria to scientifically determine non-compliance, rather than relying solely on descriptive assessments.

4. Results and Discussion

4.1 General Description and Technical Specifications

The MT Giat Armada Bersama 04 is a tanker vessel (LOA: 90m, 3474 GT) utilizing a standard mooring configuration consisting of head, stern, and spring lines. The vessel is equipped with hydraulic mooring winches operating in tandem with 8-inch polypropylene mooring lines. The original specifications of these lines dictate a high initial Minimum Breaking Load (MBL) designed to safely secure the vessel's tonnage; however, the deck equipment configuration relies on cast-iron bitts and roller fairleads that require continuous anti-corrosion maintenance.

SPECIFICATIONS

GENERAL		CARGO ARRANGEMENTS	
Name	GIAT ARMADA 04	Cargo Tanks	12
Flag	INDONESIA	Total Capacity (M3)	6973.68 at 98%
Port Of Registry	BATAM	Main Cargo Pumps	2 Units @ 702m3/hr
		Stripping	1 Unit Rotary
Year	1996		
Place Of Built	Singapore	**MACHINERY**	
Imo Number	9152985	Maine Engine	Yanmar M220 - EN 865kw/800rpm
Class Society	BKI	Propeller	Fixed pitch 4 blades
P & I		Generator	3 units Detroit Series 71
PARTICULARS			150kw x 2
Type Of Vessel	OIL TANKER	Emergency Generator	1 Unit (Airman) spesc terlampir
Draft (M)	6.5m	**PERFORMANCE**	
Gross Tonnage	3474	Speed Ballast	11 Knts
LOA	90	Speed Laden	10.5 Knts
Ballast Tank Capacity (BT 02C & 03P 03S, BT 01 tidak ada data)	176.74 m3		
Bunker Capacity	195 m3		
Fresh Water Capacity	92 m3		

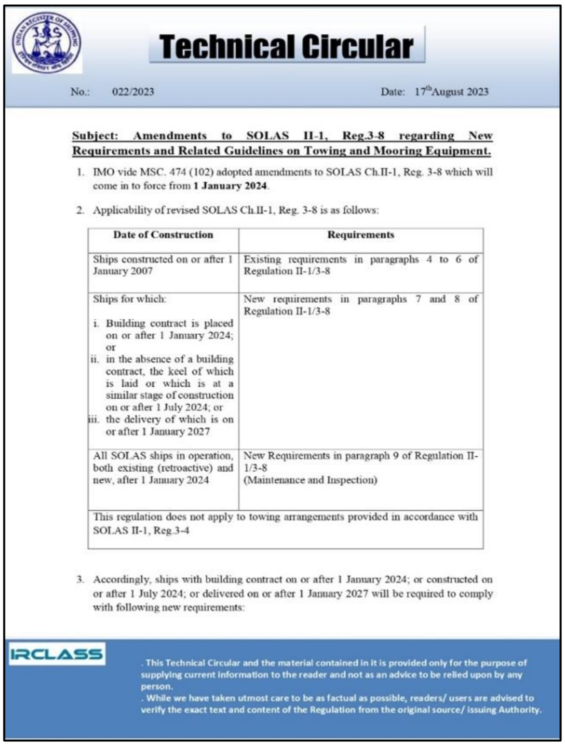
Fig 1. Ship Particular

4.2 Measurable Research Results

a. Observational Data: Field observations identified critical physical degradation in the 8-inch spring lines. Based on inspection parameters, the ropes exhibited significant localized abrasion, with broken strands visibly exceeding the 10% threshold in areas bearing the highest friction. Furthermore, severe bird-caging and a measurable reduction in rope diameter indicated advanced internal core fatigue. The supporting deck chocks displayed heavy oxidation and pitting, drastically increasing the friction coefficient.

b. Interview Findings: Thematic coding of the interviews corroborated the observational data. The Chief Officer explicitly noted the loss of mechanical elasticity, stating, *"The spring lines have lost their structural integrity and elasticity; when we heave under tension, the winch struggles significantly because the swollen, frayed lines continuously jam inside the rusted chocks, completely disrupting our timing"*.

c. Documentation Data: Document analysis confirmed a systemic non-compliance with SOLAS II-1/3-8 and OCIMF MEG4. The vessel failed to maintain an updated Line Management Plan (LMP), lacked documented tracking of line operational hours, and utilized ropes that had clearly



Technical Circular

No.: 022/2023 Date: 17th August 2023

Subject: Amendments to SOLAS II-1, Reg.3-8 regarding New Requirements and Related Guidelines on Towing and Mooring Equipment.

1. IMO vide MSC. 474 (102) adopted amendments to SOLAS Ch.II-1, Reg. 3-8 which will come in to force from **1 January 2024**.
2. Applicability of revised SOLAS Ch.II-1, Reg. 3-8 is as follows:

Date of Construction	Requirements
Ships constructed on or after 1 January 2007	Existing requirements in paragraphs 4 to 6 of Regulation II-1/3-8
Ships for which: i. Building contract is placed on or after 1 January 2024; or ii. in the absence of a building contract, the keel of which is laid or which is at a similar stage of construction on or after 1 July 2024; or iii. the delivery of which is on or after 1 January 2027	New requirements in paragraphs 7 and 8 of Regulation II-1/3-8
All SOLAS ships in operation, both existing (retroactive) and new, after 1 January 2024	New Requirements in paragraph 9 of Regulation II-1/3-8 (Maintenance and Inspection)
This regulation does not apply to towing arrangements provided in accordance with SOLAS II-1, Reg.3-4	

3. Accordingly, ships with building contract on or after 1 January 2024; or constructed on or after 1 July 2024; or delivered on or after 1 January 2027 will be required to comply with following new requirements:

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. While we have taken utmost care to be as factual as possible, readers/ users are advised to verify the exact text and content of the Regulation from the original source/ issuing Authority.

Fig 2. SOLAS II-1/3-8

4.3 Discussion and Engineering Implications

The configuration of the mooring lines is theoretically correct; however, the engineering implications of the identified deficiencies are severe. Unlike the findings of Yupiter et al. (2024), which focused primarily on external environmental wave loads, this study reveals that internal mechanical friction and material fatigue act as equal, if not greater, threats to mooring stability.

The physical deterioration of the spring lines has drastically reduced their residual strength. Because the ropes have exceeded the MEG4 retirement criteria (e.g., >10% broken strands and severe bird-caging), their actual breaking threshold is dangerously compromised, lowering the safety margin between the Working Load Limit (WLL) and catastrophic failure. Furthermore, the corroded state of the deck fittings prevents the smooth transmission of tension from the hydraulic winch. This excessive friction not only accelerates the localized thermal degradation of the synthetic fibers but also forces the deck crew to manually intervene to clear jammed ropes, directly violating safe operational practices and resulting in consistent 10 to 15-minute berthing delays.

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MSC.1/Circ.1620
24 December 2020

GUIDELINES FOR INSPECTION AND MAINTENANCE OF MOORING EQUIPMENT INCLUDING LINES

1 The Maritime Safety Committee, at its 102nd session (4 to 11 November 2020), having considered a proposal by the Sub-Committee on Ship Design and Construction, at its sixth session, and recognizing the importance of inspection and maintenance of mooring equipment including lines, approved the *Guidelines for inspection and maintenance of mooring equipment including lines*, as set out in the annex.

2 Member States are invited to bring the annexed Guidelines to the attention of shipowners, ship managers, bareboat charterers and other organizations or persons responsible for operation of ships.

3 Member States are also invited to bring the annexed Guidelines to the attention of shipmasters, ships' officers and crew and all other parties concerned, for providing guidance on inspection and maintenance of mooring equipment including mooring lines.

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Fig 3. MSC.1/Circ.1619-1620

5. Conclusion

The configuration of the mooring lines on the MT Giat Armada Bersama 04 is theoretically accurate; however, the berthing process is significantly hindered by the physical degradation of the spring lines and corroded deck fittings. Issues such as weathering, bird-caging, poor eye splices, and rusted chocks increase mechanical friction, causing the ropes to jam. This consequently delays tensioning procedures, slows down the overall berthing operation, and elevates occupational safety risks for the deck crew, demonstrating that operational precision relies as much on physical material quality as it does on correct rope configuration.

To resolve these operational bottlenecks, ship management must prioritize the immediate replacement of unseaworthy mooring lines and conduct rigorous routine inspections of all rope splices to ensure structural integrity. Furthermore, it is imperative to execute systematic cleaning and anti-corrosion maintenance on all supporting deck components, including bitts, chocks, and fairleads. Restoring these physical assets will minimize rope friction, prevent line tangling, and facilitate a smoother mechanical operation during the berthing sequence.

Operationally, the vessel must enforce a strict Line Management Plan (LMP) in alignment with OCIMF MEG4 and IMO safety standards to dictate clear retirement criteria for degrading ropes. This strategic management must be coupled with comprehensive pre-berthing equipment inspections and enhanced crew supervision, particularly during adverse weather conditions. By combining physical equipment maintenance with disciplined operational procedures, the vessel can ensure that the berthing process is executed safely, efficiently, and without technical delays.

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