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Optimization of Ballast Water Management System on MV Sun Winner II to Ensure Operational Stability During Port Cargo Handling

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Abstract

The stability of bulk carriers during high-rate cargo operations represents a critical intersection of naval architecture, mechanical engineering, and operational management. This study investigates the systemic inefficiencies in the ballast water management system of the MV Sun Winner II, a Supramax bulk carrier operating in the Indonesian archipelago, specifically analyzing the technical impediments encountered during cargo handling at Muara Berau port on February 14, 2024. Utilizing a descriptive qualitative methodology, data were acquired through direct shipboard observations, semi-structured interviews with senior deck officers, and rigorous documentation analysis over a 12-month sea service period. The research identifies a significant degradation in ballast performance attributed to sediment accumulation (sludge) exceeding 2 cm in tank bottoms, advanced corrosion of suction valves, and reduced centrifugal pump efficiency, which collectively resulted in a cargo intake shortfall of approximately 2,000 metric tons against a planned 23,000-ton capacity. The study reveals a critical dissonance between the administrative Planned Maintenance System (PMS) records and the physical reality of the vessel's ballast infrastructure, highlighting the "administrative-physical gap" as a latent risk factor. The findings suggest that on aging vessels (25+ years), standard maintenance protocols are insufficient; an enhanced regime of predictive maintenance, aggressive de-silting, and comprehensive valve overhauls is required to ensure compliance with SOLAS stability criteria and to maximize commercial voyage capability.

Keywords: *Ship Stability, Ballast Water Management, Bulk Carrier Operations, Sediment Accumulation, Planned Maintenance System (PMS).*

1. Introduction

The maritime transport sector constitutes the backbone of global commerce, with bulk carriers facilitating the movement of essential raw materials such as coal, iron ore, and grains. Within this logistical framework, the seaworthiness of a vessel is predicated not merely on its structural integrity but fundamentally on its stability—the hydrodynamic ability to return to an equilibrium position after external perturbations. For bulk carriers like the MV Sun Winner II, stability is a dynamic variable that fluctuates significantly during port operations, particularly during the rapid loading and discharging of cargo. The preservation of a positive metacentric height (GM) and the effective management of trim and list are contingent upon the precise operation of the vessel's ballast system.However, the operational reality of aging fleets often diverges from theoretical design parameters. The MV Sun Winner II, having been in service for over two decades since its construction in 1998, presents a case study in the degradation of auxiliary systems.

The vessel's operational history reveals a pattern of stability-related challenges, most notably observed during a loading operation on February 14, 2024, at the Muara Berau anchorage in East Kalimantan. During this operation, the vessel experienced a critical inability to de-ballast effectively, forcing a premature cessation of cargo loading. Specifically, while the load plan targeted a cargo intake of 23,000 metric tons, the vessel was restricted to 21,000 tons due to the retention of "dead ballast"—water that could not be pumped out due to system inefficiencies.This incident is not an isolated mechanical failure but symptomatic of broader systemic issues involving sediment management and corrosion control in ballast tanks. The accumulation of sedimentary deposits, often referred to as sludge, acts as a physical barrier to suction bellmouths and reduces the effective volume of tanks. Furthermore, the corrosive marine environment accelerates the deterioration of piping and valve mechanisms, leading to increased friction losses and reduced pump suction head.

These factors collectively compromise the vessel's ability to adjust its trim and draft in response to high-speed shore loaders, thereby risking structural stress events (hogging/sagging) and reducing the commercial efficiency of the voyage.The regulatory landscape, governed by the International Maritime Organization (IMO) through conventions such as SOLAS (Safety of Life at Sea) and the BWMC (Ballast Water Management Convention), mandates rigorous maintenance of these systems. Additionally, national regulations, including the Indonesian Law No. 17 of 2008 on Shipping and its recent amendment in Law No. 66 of 2024, emphasize the legal obligation of ship operators to maintain safety standards. Despite these frameworks, the disconnect between the "paper" compliance recorded in maintenance logs and the "physical" condition of the tanks remains a persistent industry challenge.

Picture 1. MV. Sun Winner II

2. Research Methodology

2.1 Previous Studies

This research builds upon several key studies in the field of maritime operations:

- **Rifqi Al Usman (2021)** investigated the *MV Meratus Medan 1* and found that ballast pump pressure drops were primarily caused by sea chest blockages and delays in spare part procurement. His study emphasized the role of the Planned Maintenance System (PMS) in preventing stability loss.[1]

- **Sahusilawane (2023)** analyzed the *MV Hijau Jelita* and focused on the structural integrity of tanks. He identified corrosion as the root cause of leaks between ballast and cargo spaces, recommending zinc anode replacement and coating repairs as primary mitigations.[1]

- **Pratama (2024)** studied the *MV DK 02*, concluding that suboptimal ballast discharge was linked to valve failures and piping leaks. His work highlighted the direct correlation between component health and discharging delays.[1]

Unlike these previous studies, which often focused on single failure modes (e.g., only corrosion or only blockage), the current research on the MV Sun Winner II integrates these factors to analyze the *cumulative* impact of age-related degradation on commercial cargo capacity.

2.2 Theoretical Framework of Ship Stability and Ballast Systems

Ballast water is defined as water with its suspended matter taken on board a ship to control trim, list, draught, stability, or stresses of the ship.[4] In the context of the MV Sun Winner II, the ballast system serves as the primary

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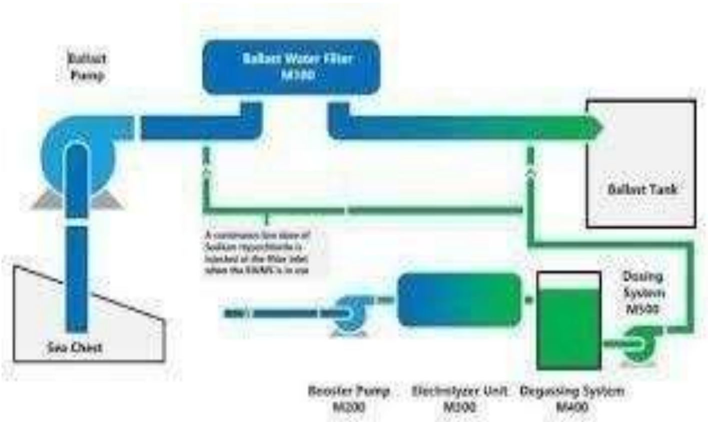
mechanism for counteracting the shifting centers of gravity (*G*) during cargo operations. The fundamental principle of stability relies on the relationship between the center of gravity (*G*), the center of buoyancy (*M*), and the metacenter (*M*). The metacentric height (*GM*), calculated as *KM* - *KG*, serves as the index of initial stability.



Picture 2. Ballast Water Filter

During loading, the addition of cargo raises the ship's *G*. Without the simultaneous discharge of ballast water from the double bottom tanks (which are low in the ship's structure), the *G* would rise dangerously close to *M*, reducing the righting lever (*GZ*) and compromising the vessel's ability to resist heeling moments. Conversely, during discharge, the removal of low-density cargo must be compensated by taking in ballast to ensure propeller immersion and prevent excessive stiffness (a very large *GM*), which can cause violent rolling.

The effectiveness of this system is mathematically governed by the flow rate (*Q*) of the ballast pumps and the head loss (H_L) in the piping system. Corrosion in pipes increases the roughness coefficient, thereby increasing friction head loss and reducing the effective flow rate.

$$H_L = f \cdot \frac{L}{D} \cdot \frac{v^2}{2g}$$

Where *f* is the Darcy friction factor, *L* is pipe length, *D* is diameter, and *v* is fluid velocity. The accumulation of scale and sediment increases *f* and decreases *D*, leading to the "unpumpable" ballast scenarios observed on older vessels.

2.3 Operational Procedures in Cargo Handling

Cargo handling in bulk carriers involves the interaction of shore-based equipment (loaders/unloaders) and ship-based systems (ballast/de-ballasting). The efficiency of this interface determines the Port Turnaround Time.[7] The *Safety of Life at Sea* (SOLAS) convention, Chapter VI, Regulation 7, requires that loading and unloading of bulk cargo be carried out in accordance with a plan agreed upon between the master and the terminal representative.[1] This plan must account for the synchronicity between the cargo rate (tons/hour) and the ballast pump rate ($m^3/hour$).

If the ballast pumps cannot keep pace with the cargo loader due to mechanical inefficiency, the ship may develop excessive trim or list. Excessive trim can twist the hull structure, while list can cause damage to hatch coamings and loading equipment. Therefore, the operational effectiveness of the vessel is inextricably linked to the hydraulic performance of the ballast system.

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Picture 3. Cargo Handling

2.4 Factors Affecting Ballast System Efficiency

Several technical factors degrade ballast system performance over time:

- **Sediment Accumulation:** Ballast water taken in shallow ports often contains high loads of suspended solids. Over time, these settle as sludge in the tank bottoms. Studies indicate that compacted sediment not only reduces cargo lift capacity but also blocks drainage channels (limber holes) and suction bells.

- **Corrosion:** The cyclic wetting and drying of ballast tanks, combined with the high oxygen content of seawater, create an ideal environment for oxidation. Pitting corrosion can lead to structural failure, while general corrosion creates scale that clogs valves and filters.

- **Biofouling:** The growth of marine organisms in sea chests and piping can severely restrict intake flow, leading to pump cavitation.

Picture 4. Ballast Control Room

3. Results and Discussion

3.1 General Description of the Research Object

The MV Sun Winner II is a bulk carrier with a Deadweight Tonnage (DWT) of 72,928 MT (Summer), built in 1998 by Hudong Shipyard.[1] The vessel features seven cargo holds and a comprehensive ballast system comprising Fore Peak (FPT), After Peak (APT), and five pairs of Double Bottom/Wing Tanks (WBT/DBT 1-5 P&S). The ballast system is powered by two main centrifugal pumps (Kwasner) with a rated capacity of *1200 m^3/hr* each. The control infrastructure is located in the Ballast Control Room, utilizing a hydraulic valve remote control system.


CREW LIST
Arrival
Departure
Page 1
MASTER

Picture 5. Crew List

3.2 Findings: The Muara Berau Incident

The primary case analysis focuses on the loading operation at Muara Berau on February 14, 2024. The vessel was scheduled to load 23,000 MT of coal via ship-to-ship transfer. However, the final bill of lading recorded only 21,000 MT.

- **Observation of Failure:** During the final stages of de-ballasting, the pumps lost suction while significant water remained in the tanks. Sounding tapes indicated "empty," but the vessel's draft readings and displacement calculations confirmed the presence of approximately 2,000 tons of unpumpable ballast.[1]

- **Physical Inspection:** Subsequent inspection of the tanks revealed heavy sedimentation. In the Double Bottom tanks, sludge layers of 1-2 cm were ubiquitous, with localized accumulations near suction bays reaching higher levels. This sediment created a viscous slurry that the centrifugal pumps could not lift once the hydrostatic head pressure dropped.

Picture 6. Sludge Removal

3.3 Analysis of Technical Factors

The research identified three critical technical factors contributing to this inefficiency:

3.3.1 Sediment Accumulation (Sludge)

The presence of mud and silt in the tanks is a direct consequence of trading in riverine ports like Samarinda. The sediment accumulation has two effects:

1. **Volume Reduction:** It occupies space meant for ballast water, though this is minor compared to the weight issue.
2. **Suction Blockage:** The sediment clogs the strum boxes (filters) on the suction lines. When the water level is low, the pump draws a mixture of air, water, and mud, leading to cavitation and loss of prime.

3.3.2 Corrosion and Valve Failure

Visual documentation (Figure 4.5 in the thesis source) confirmed extensive corrosion on the valve bodies and flanges. The "stiffness" of the hydraulic valves meant they often failed to close or open fully.

- **Impact:** A partially open valve on a suction line allows air to enter the system, breaking the vacuum required for stripping tanks. During the Muara Berau operation, crew members had to manually operate valves on deck, causing significant delays and disrupting the synchronization with the shore loader.[1]

3.3.3 Pump Performance Degradation

The Kwasner pumps, rated for $1200\ m^3/hr$, were observed operating at significantly lower effective rates. The wear on the impellers (due to processing sediment-laden water over 25 years) has likely increased the internal clearances, reducing the hydraulic efficiency. This necessitates longer pump run-times to move the same volume of water, consuming more fuel and delaying cargo ops.

Picture 7. rust found in ballast tank and valve ballast

3.4 Interview Analysis and Triangulation

The interviews with the Chief Officer (Informant 1) and Third Officer (Informant 2) provided crucial context to the physical findings.

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Table 1: Summary of Key Interview Insights

Theme	Chief Officer (Informant 1)	Third Officer (Informant 2)	Synthesis
Procedures	Defined as planned actions based on Loading/Ballast Plans and Stability Booklets.	Operational steps executed under senior orders to monitor draft, trim, and list.	Procedures are well-understood theoretically but are hampered by execution realities.
Challenges	Cited sludge accumulation, corrosion of pipes/valves, and pump pressure drops as primary barriers.	Highlighted difficult valve operation due to rust and rapid stability changes requiring constant monitoring.	Technical degradation is the universal constraint acknowledged by all ranks.
Effectiveness Factors	Planning accuracy, technical condition of tanks/pumps, and deck-engine coordination.	Crew discipline, supervision intensity, and prompt communication of technical issues.	Effectiveness is a product of Mechanical Health x Human Vigilance.

The triangulation of these interviews with the maintenance logs reveals a disturbing "Administrative-Physical Gap." The monthly reports often checked "Satisfactory" for tank conditions, while physical inspections showed heavy scaling and sludge. This suggests that the PMS is being treated as a paperwork exercise rather than a driver of actual maintenance.

3.5 Discussion: The Operational and Economic Implications

The inability to de-ballast 2,000 tons of water translates directly to lost revenue. In the bulk trade, freight rates are calculated per ton; thus, "dead ballast" is essentially "dead freight." Furthermore, the stability implications are severe. The "Free Surface Effect" (FSE) of the unpumpable water/sludge mixture reduces the vessel's GM more than solid weight would. As the vessel rolls, this slurry shifts, creating a dynamic reduction in stability that is difficult to calculate precisely.

The "stiff" valves and blocked lines force the crew into reactive management—fixing problems as they arise during loading—rather than proactive management. This reactive stance increases the risk of human error, as officers are distracted by troubleshooting rather than monitoring the overall stability plan. The findings align with Rifqi Al Usman (2021) regarding the criticality of PMS application, but go further to quantify the capacity loss.

The correlation between the *age* of the vessel (26 years at the time of the incident) and the failure mode is evident. The corrosion described by Sahusilawane (2023) is present here, but it is the *sediment* identified by the current study that acts as the primary operational choke point.

Picture 8. Maintenance Ballast Tank

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4. Conclusion

The research concludes that the ballast regulation system on the MV Sun Winner II operates at a suboptimal level, directly compromising the vessel's operational stability and commercial efficiency. 1). Procedural Effectiveness: While the standard operating procedures (ballast planning) are theoretically sound and understood by the officers, their execution is derailed by the physical degradation of the system. The procedure of "stripping" tanks is frequently incomplete due to loss of suction. 2). Dominant Factors: The primary factors inhibiting effectiveness are Sediment Accumulation (blocking suction), Corrosion (impairing valve actuation), and Pump Wear (reducing rate). These technical failures forced a cargo reduction of 2,000 tons during the Muara Berau call. 3). Maintenance Gap: There is a critical disconnect between the recorded maintenance (PMS) and the actual condition of the tanks, indicating a need for more rigorous verification protocols.

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