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OPTIMIZING MARITIME INDUSTRY MANAGEMENT: AN INNOVATIVE LEAK REPAIR TECHNIQUE FOR BALLAST AND CARGO TANKS

OPTIMALISASI PENGELOLAAN INDUSTRI MARITIM: SEBUAH INOVASI TEKNIK PERBAIKAN KEBOCORAN PADA TANGKI BALLAST DAN CARGO

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ABSTRACT

The operation of ships at sea involves various risks, including damage to the ship's structure, particularly to the ballast tanks and cargo tanks. Leaks in these tanks can cause significant financial losses, seriously impact the environment, and even threaten lives at sea. Therefore, this study aims to analyze the causes of leaks in ballast tanks and implement repair techniques used to address leaks in the ballast and cargo tanks on the vessel MT. Sepinggan. It also evaluates maintenance practices that include technical patching procedures and regular docking as part of ship management strategies. This research uses field research methods and literature studies with a qualitative descriptive approach, where the research sample is taken through purposive sampling with MT Sepinggan as the research object. The study shows leaks in the ballast tanks of MT. Sepinggan is caused by delayed docking and a lack of routine maintenance, which makes the tank plates thin and prone to leakage. Repair techniques, including patching procedures and regular docking schedules, have proven effective in addressing leaks and improving ship management. Limited funds and uncertainty of ship operational routes also resulted in irregular maintenance schedules.

Keywords: ballast tank leakage, patching technique, ship construction damage, ship management.

ABSTRAK

Operasi kapal di laut memiliki berbagai risiko, termasuk kerusakan pada konstruksi kapal, terutama pada tangki ballast dan tangki kargo. Kebocoran dalam tangki-tangki ini dapat menyebabkan kerugian finansial yang signifikan, berdampak serius pada lingkungan, bahkan mengancam nyawa di laut. Oleh karena itu, penelitian ini bertujuan untuk menganalisis penyebab kebocoran tangki ballast dan menerapkan teknik perbaikan yang digunakan untuk mengatasi kebocoran dalam tangki ballast dan muatan pada kapal MT. Sepinggan, serta untuk mengevaluasi praktik pemeliharaan yang mencakup prosedur teknis tambalan dan *docking* secara teratur sebagai bagian dari strategi pengelolaan kapal. Penelitian ini menggunakan metode penelitian lapangan dan studi pustaka dengan pendekatan deskriptif kualitatif, di mana sampel penelitian diambil secara purposive sampling dengan MT. Sepinggan sebagai objek penelitian. Penelitian menunjukkan bahwa kebocoran tangki ballast pada MT. Sepinggan disebabkan oleh keterlambatan docking dan kurangnya perawatan rutin. Teknik perbaikan yang termasuk prosedur tambalan dan jadwal *docking* teratur terbukti efektif dalam mengatasi kebocoran dan memperbaiki manajemen kapal. Keterbatasan dana dan ketidakpastian rute operasional kapal juga mengakibatkan jadwal perawatan tidak teratur.

Kata kunci: kebocoran tangki pemberat, teknik penambalan, kerusakan konstruksi kapal, manajemen kapal.

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INTRODUCTION

The shipping industry plays a crucial role in supporting the global economy. Ships worldwide transport various goods, including oil and fuel, vital commodities for many countries (Tong, 2022; X. Wang et al., 2020). However, ship operations at sea are not without risks, including damage to the ship's structure, especially the ballast and cargo tanks (Valković & Obhođaš, 2020). Leaks in these tanks can result in significant financial losses, pose serious environmental threats, and even endanger lives at sea (Kuznecovs et al., 2023). The ballast tank is an essential ship component, providing stability by filling or emptying seawater into or from the tank (Liu et al., 2022; Y. Wang et al., 2023). On the other hand, the cargo tank is the primary storage for goods or cargo transported by the ship. Both tanks must always be in prime condition to ensure the safety and efficiency of ship operations (Alkhoori et al., 2021; Leivestad, 2021; D. Song, 2021). However, many ships experience leaks in these tanks due to age, corrosion, or other mechanical damage (Kim et al., 2020; Puisa et al., 2019).

An example can be seen in an incident involving the MT. Sepinggan ship on November 19, 2015, highlights the critical nature of tank leaks for ship operations. While the ship was loading oil in Balikpapan, a seeping sound was heard from the left ballast tank No. 3. Further inspection revealed that oil from the cargo tank had leaked into the ballast tank. This incident halted the loading operation and forced the ship to anchor and undergo emergency repairs. A leak between the ballast and cargo tanks can have fatal consequences. Besides environmental pollution risks, leaks can disrupt the ship's balance and increase the risk of sinking. Therefore, innovations in patching leaks in ballast and cargo tanks are crucial. New technologies and methods for detecting, preventing, and repairing leaks can significantly enhance ship safety and sustainability.

Routine ship maintenance and care are the first steps in preventing leaks. However, given the complexity of ship structures and operations and the harsh marine environment, leaks can occur anytime (Fadeeva & Van Berkel, 2021; Winterstetter et al., 2021). Hence, the industry needs to invest in research and development technologies that can quickly and accurately detect leaks and efficient, durable repair methods. Additionally, crew training and education are vital. They must be equipped with the knowledge and skills to identify early signs of leaks and take preventive measures before situations become critical. Collaboration between ship owners, port authorities, and related industries is also needed to address every leak incident promptly and effectively (Koh et al., 2022; Kubacka et al., 2022; Puisa et al., 2019).

In this context, the research aims to analyze the causes of ballast tank leaks and apply repair techniques used to address leaks in the ballast and cargo tanks of the MT Sepinggan ship, as well as to evaluate maintenance practices that include technical patch procedures and regular docking as part of the ship management strategy. Thus, this study contributes to ocean protection and conservation. Developing more effective leak patching methods and early detection technology can minimize the risk of oil or chemical spills into the sea. This protects the vulnerable marine ecosystem and maintains the quality of seawater and its biodiversity. Moreover, by preventing leaks, ships can

operate more safely and efficiently, reducing the risk of accidents that could further harm the marine environment. Therefore, this research supports global efforts to maintain the sustainability and balance of marine ecosystems, which are life sources for millions of species and humans.

RESEARCH METHODS

The methods used to collect research data are field research methods and literature study methods, which are descriptive with a qualitative research approach. This is done by directly reviewing the object being studied and describing the problems being investigated. Additionally, the qualitative research approach involves collecting data in the form of words or images, not numbers (Sugiyono, 2019). In compiling or completing this research, concrete data is required as a material for analysis in writing the main topic and its problems. This research uses 12 ships as the research population, as follows:

Table 1. Research Population

No	Ship	Type
1.	MT Pangkalan Brandan	GP
2.	MT Pasman	GP
3.	MT Parigi	GP
4.	MT Panjang	GP
5.	MT Sepinggan	GP
6.	Fastron	MR
7.	PIS Paragon	MR
8.	PIS Polaris	MR
9.	Sambu	MR
10.	MT Hauhau	Small
11.	MT Musi	Small
12.	MT Matindok	Small

Notes: GP (General Purpose), refers to ships designed for versatile cargo handling. MR (Medium Range), describes ships typically used for transporting refined petroleum products over moderate distances. Small refers to smaller-sized vessels, often used for specific purposes like regional transport or specialized cargo.

The sample selection uses a purposive sampling technique, which is a sampling technique with specific considerations. The criteria used are: (1) the selected ship must have a history of ballast tank leaks; (2) the ship must still be operational; (3) the ship must have complete and documented records regarding the inspection, repair, and maintenance of ballast tanks for the analysis of leak causes and evaluation of repair techniques; and (4) the ship's management and crew must be willing and cooperative to participate in this research. Based on these criteria, this research was conducted on the MT Sepinggan ship.

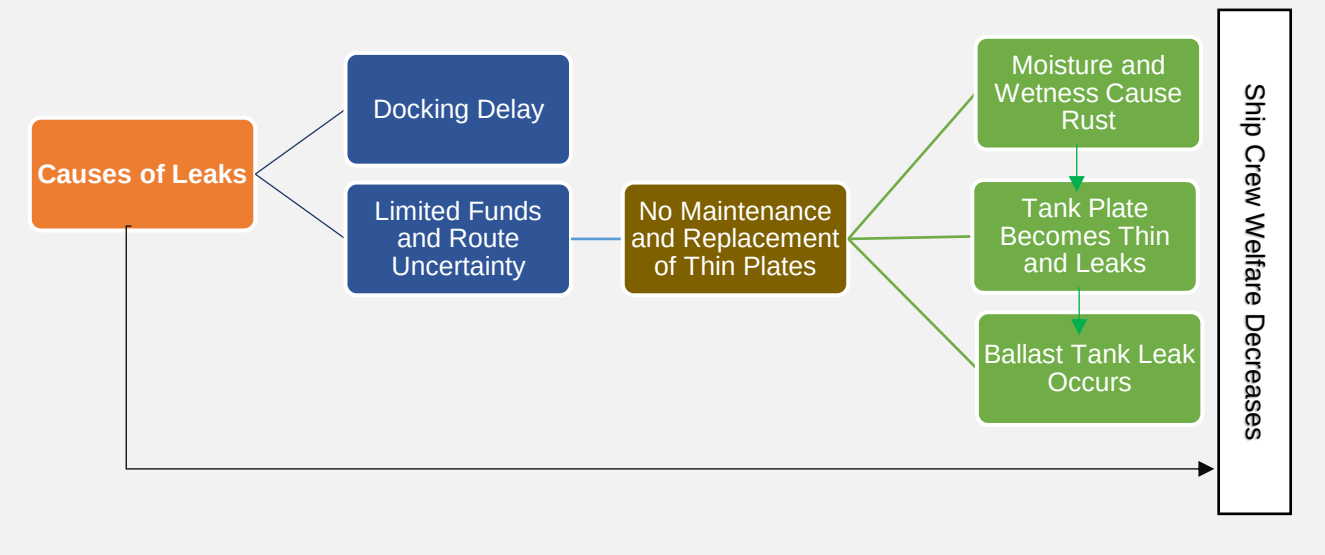
Data and information are collected through observation, which involves directly observing the ship's location to inspect the physical condition of the ballast tanks and the surrounding areas. This observation includes examining the tank plates, identifying leaking areas, and assessing corrosion or material wear conditions. Interviews are also conducted with the ship's crew, including the Chief Officer and technicians, to gain an understanding of the existing issues. Documentation is aimed at obtaining direct data from the scene, including relevant books, activity reports, regulations, photos, and relevant research data. In this research, repair activities are documented during the ship's repair

process, which helps analyze the effectiveness of various repair techniques used and compare conditions before and after repairs. Furthermore, a literature study is conducted to gain a deeper understanding of the literature, books, and writings related to the discussed problems, providing a strong theoretical foundation in discussing the researched issues, including the crew's understanding of ballast tank plate maintenance.

RESULT AND DISCUSSION

Leaks are an essential part of understanding sea vessels, and this research focuses on the leakage of ballast tanks on the MT. Sepinggan PT. Pertamina (Persero). Based on observation results, findings were made regarding the causes of leaks in the ballast tank and how to overcome them. In addressing this issue, the researcher sought solutions to prevent or address what happened to the ballast tank, which needed immediate repair.

Causes of Ballast Tank Leaks on the MT. Sepinggan Ship



Source: Primary Data (2024)

Figure 1. Causes of Ballast Tank Leaks on MT. Sepinggan Ship

The causes of the ballast tank leaks on the MT. Sepinggan ship is as follows:

First, the company's delay in docking its fleet, MT. Sepinggan, for the repair and replacement of thin ballast tank plates.

The company delayed docking its fleet in MT. Sepinggan can be determined by observing the last docking of the MT. Sepinggan vessel. Researchers found that MT. Sepinggan last docked in 2012 by examining the dock photos in the MT. Sepinggan computer bridge and the Condition Assessment Scheme (CAS) certificate, which is a condition assessment certificate adopted by the International Maritime Organization through MEPC'94 (46) resolution concerning the operation of single-hull oil tankers, where the ship inspection indicated that the overall structural condition of the

vessel was satisfactory and met the requirements (Minister of Transportation of the Republic of Indonesia, 2014). Researchers discovered that the CAS (Condition Assessment Scheme) certificate for MT. Sepinggan expired in June 2015, and the printout of this certificate, along with the details/documents of the last MT. Sepinggan Dock shows that the requirement for renewing the Condition Assessment Scheme (CAS) certificate is to perform docking. According to the Director General of Marine Affairs Decree No.HK.103/1/4/DJPL-14, the Director General of Marine Affairs, Capt, issued the latest regulation on docking (dry-docking) of Red-White flagged vessels. Bobby Mamahit signed this new regulation on January 30, 2014. The regulation consists of Chapter V and 14 articles, namely passenger ships must undergo inspection or docking every year, just like the previous regulation (Direktorat Jenderal Perhubungan Laut, 2014).

The regulations regarding the docking of non-passenger ships are divided into two. For Class A90, renewal docking must be performed every four years, while intermediate docking must be done every two years, thus concluding that Red-White flagged ships must dock every two years. For Class A-100 ships, renewal surveys must be performed every five years, while intermediate surveys must be conducted between the 2nd and 3rd years. Therefore, every 2.5 years, A100 ships must dock (Direktorat Jenderal Perhubungan Laut, 2014). Hence, it can be concluded that MT. Sepinggan was late in performing docking, which should have been done by June 2015. The delay in docking for several months resulted in a ballast tank leakage due to the lack of maintenance and replacement of the thin ballast tank plates. The ballast tank leakage occurred in November 2015. With a regular docking schedule, maintenance and repairs to prevent more severe ship damage can be anticipated as early as possible; thus, the handling does not require more time and cost.

Second, Limited Funds and Uncertain Ship Operating Routes

This can result in ships not undergoing regular docking and special maintenance rotations (special surveys), leading to rusting and causing the plates to become thin and leaky. The known cause of the lack of maintenance is moisture or wetness, which can be addressed with proper maintenance. With the delay in docking, perfect and thorough maintenance cannot be carried out as expected, causing this condition to persist. Iron will not rust in dry air or pure water. However, if air and water are present together, iron, especially steel, will rust quickly (Li et al., 2020; Refait et al., 2020). The rate of rusting will not decrease because the formed corrosion layer will peel off, leading to the formation of a new rust layer underneath, which will in turn release the layer above it. Therefore, if the maintenance of the keel plates and other parts of the ship is neglected, rust will accumulate, causing the plates to become thin and leaky. Based on observations, the company employs an expensive docking maintenance strategy and delays the docking schedule until a certain level of damage requires special handling. In this case, the company aims to minimize operational costs in operating its ships to maximize profits. However, since the maintenance standards applied are not optimal, the company's goal of maximizing profits cannot be realized. As the company aims to maximize profits, the welfare of the ship's crew cannot be improved and may even decline.

Problem-Solving

The solution to the problem was based on observations on the MT. Sepinggan ship regarding how to prevent an incident like a ballast tank leak is as follows:

First, the company should not delay docking its fleet

The delay in implementing docking for ships can result in unwanted fatal incidents, such as what happened on MT: Sepinggan, namely the leakage of the ballast tank. Therefore, shipping companies must pay attention to their fleet's regular and timely docking schedule.

Second, the Docking Repair Work Plan

The docking repair schedule is determined based on the validity period of the ship's documents or the provisions of the Classification Society and the Government. According to the regulations, the docking schedule is carried out every two years for the Annual Survey and every five years for the Special Survey (Direktorat Jenderal Perhubungan Laut, 2014). The Owner Superintendent (OS) prepares the Ship Maintenance Plan or Plan Maintenance System (PMS) by considering the type of survey, the last docking report, unresolved class recommendations, the due date of class items, current information from Ship Management, and unresolved issues from previous repairs. The estimated docking repair time is calculated carefully, taking into account the planned work volume.

Third, Running Repair Work Plan

The running repair work plan for ship maintenance is based on not interfering with ship operations and the availability of work equipment, materials, or spare parts. And still, we have to calculate the execution time. This Running Repair is implemented based on the Plan Maintenance System (PMS) that has been prepared and determined. The Owner Superintendent (OS) is responsible for the smooth implementation and coordinates with the Procurement Department to ensure that the required materials, equipment, or spare parts are available before the Running Repair work.

Fourth, Preparation of the Docking Repair List

The Ship Board Management prepares the initial repair list for docking repair according to each function. The Deck Department is prepared by the Chief Officer, the Engine Department is prepared by the KKM, and Radio/Navigation is prepared by the 2nd Officer. All are known and signed by the ship's Captain: (1) The repair list should be detailed, including the work type, volume, size, location, and material or spare part needs. (2) The Owner Superintendent must first examine the initial repair list signed by the captain and then recompile it into a complete Docking Repair List in a predetermined form or format. (3) The Docking Repair List approved by the Director becomes the Final Docking Repair List and must be prepared at least three months before due for docking to allow enough time for the bidding process to the dockyard.

Fifth, Preparation of the Running Repair List

According to the established format, the owner-superintendent prepares the Running Repair list based on the ship captain's damage report or the class survey due date. They were forwarded to the Director for approval. The Deck Department's Chief Engineer prepares the damage report for

the Engine Department and the 2nd Officer for Radio and Navigation. The captain examines and knows this report and the damage report must contain complete information. The Superintendent examines and considers the level of difficulty of the damage that arises and provides suggestions/input to the leadership on whether the crew can repair the damage or if it must be handed over to a third party.

Sixth, Estimation of Costs

The Final Repair List, both for Docking Repair and Running Repair, approved by the Director, is forwarded to the Procurement or Logistics Department to estimate costs, execution time, and procurement of materials or spare parts (Suarna et al., 2022). Service cost estimates are calculated based on the price list (if available) or the last contract value. Meanwhile, for materials, equipment, and spare parts, the cost is estimated based on price references from agents/distributors or previous Purchase Orders (POs). The estimated costs and execution time, which have been reviewed and acknowledged by the Procurement/Logistics Department, are then forwarded to the Director for approval (Zhang et al., 2021).

Seventh, Price Offer

The final repair list for Docking Repair is sent to the shipyards at least two months before the due date for docking. At least one month before Docking, the shipyard is expected to provide a price offer and execution time. The price offer evaluation is carried out by a team consisting of the Owner Superintendent and procurement or Logistics Department, led by the Head of the Logistics Department, and involves conducting price negotiations with the bidder (Dockyard), offering the lowest price and the fastest execution time. For Running Repair, the same team evaluates the price offer and negotiates prices with the contractor, offering the lowest price and the fastest execution time. The results of the evaluation and price offer negotiations agreed upon by both parties, both for Docking Repair and Running Repair, are forwarded to the Director for approval.

Eighth, Procurement of Material Equipment Spare Parts

The Procurement / Logistics Department inventories the type and quantity of materials, equipment, and spare parts from the final repair list for Docking Repair or Running Repair. It determines which ones can be procured by themselves and which ones will be handed over to the Dockyard/contractor for procurement and then forwarded to the Head of the Logistics Department to be known and approved. The Procurement/Logistics Department requests price offers for materials, equipment, or spare parts from several agents, distributors, and contractors for each required material, equipment, or spare part. The Procurement/Logistics Department evaluates the prices from several offers and conducts price negotiations with the lowest bidder. The price evaluation results and negotiations agreed upon by both parties are forwarded to the Director for approval.

Ninth, Work Supervision

The Owner Superintendent supervises ship repair work, both docking repair and running repair, as well as damage repair. The Owner Superintendent is responsible for the smooth completion of ship repairs according to the established schedule, always coordinating with the

Procurement/Logistics Department for the smooth procurement/supply of the required materials, equipment, or spare parts. In the event of a reduction in items/work volume, the Owner-Superintendent can directly give orders to the dockyard/contractor, and then immediately report in writing the reduction in item or work volume to the Director. Suppose there is an addition of items/work volume due to either the recommendation of the Classification Body/Government or the test results. In that case, the shipboard management immediately prepares a repair request according to each Department/Department. This repair request is examined and known by the Owner Superintendent and forwarded to the Director for approval. The Owner Superintendent then delivers the additional work approved by the Director to the Dockyard/contractor to request a price offer immediately. For additional work whose main items have been approved for implementation, the Owner Superintendent can directly give orders to the Dockyard/Contractor.

Tenth, Reporting

For Docking Repair, the progress report of the work is reported by the Owner Superintendent once a week (weekly report) in writing, in the form of a percentage of completion of work items, forwarded to the Director for acknowledgment. The Dockyard prepares the final docking report, which is checked and signed by the shipboard management and acknowledged by the Owner Superintendent. For Running Repair and Damage Repair, the progress report of the work is prepared by the contractor/executor, checked and signed by the shipboard management, and acknowledged by the Owner Superintendent. The respective Department Heads prepare the running store, which is acknowledged by the Ship's Captain, and forwarded to the Company Leadership, with a copy to the Procurement/Logistics Department for recording. The final docking report and running report acknowledged and signed by the Owner Superintendent, are forwarded to the Head of the Logistics Department for acknowledgment and can be used for further processes as supporting documents. Each department documents each completed work/maintenance item. Maintenance notes include: (1) Maintenance execution time. (2) Testing execution time and test results. (3) Maintenance notes are placed near the relevant equipment in an easily visible and readable location.

They were handling the leakage of the ballast tank in MT. Sepinggan is done by patching a new iron plate adjusted to the length and width of the leaking plate section. If a leak occurs in the ballast tank, with the crew's knowledge, skills, and expertise, it is expected that they can complete tasks and solve problems on the ship. Therefore, having an educated and experienced crew to take quick and precise actions is highly hoped and demanded.

Source: Primary Data (2024)

Figure 2. Leaking Ballast Tank

The crew's actions when the ballast tank and cargo tank No. 3 left MT. SEPINGGAN experienced a leak: (a) Preparing materials: Iron Plate, Rubber Packing, Cement, Sand, Caustic Soda, Putty, Aqua Sealer, and Oil Dispersant. (b) Preparing equipment: Electric Welding Machine, Shovel, Cement Spoon, Bucket, Hammer, Fan/Blower, Lamp/Flashlight. (c) Safety Meeting: The Safety Meeting is conducted to support the safety of the MT. SEPINGGAN crew in repairing the leak on the ballast tank plate and cargo tank No. 3 left. Safety can be achieved if the factors were causing work accidents during the repair process on the ballast tank plate and cargo tank no. Three left are known, so it can be determined what steps should be taken to avoid them. The Safety Meeting can create cooperation on the ship, so work can operate smoothly and safely.

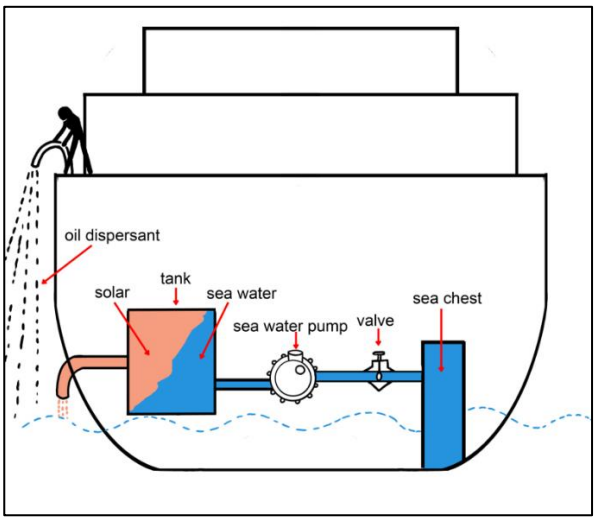
Source: Primary Data (2024)

Figure 3. Welding Process

Technical Patching Work Procedure

Observing the calm sea conditions and clear weather, the chief officer gave the order to fill the leaking left ballast tank 3 to discharge the oil that had entered the leaking left ballast tank 3. This was because the leaking ballast tank was adjacent to the ship's diesel oil cargo tank. The oil that entered was expelled through the manhole of the leaking left ballast tank three by intentionally making the left ballast tank three overflow, spilling to discharge the oil that had entered the left ballast

tank 3. With this method, the oil will exit from the left ballast tank 3 through the manhole because seawater's density/specific gravity is greater than the diesel oil loaded on the ship. Seawater's density/specific gravity is 1.025, while diesel oil's density/specific gravity is 0.800. After overflowing, the oil exits the tank through the manhole, pushed out by seawater. The ship's crew on the deck sprayed the oil with Oil Dispersant, which functions to dissolve/neutralize the oil to prevent sea pollution by oil when the oil falls into the sea.



Source: Primary Data (2024)

Figure 4. Working Procedures for Patching Techniques

This is done to ensure the safety and security of the ship's crew during the work, as the crew will handle the leakage of the left ballast tank 3 using an electric welding machine. This is the reason why oil must be drained from the ballast tank, aiming to prevent explosions or fires in the ballast tank during the leakage handling process. Once the left ballast tank three is deemed safe and oil-free, the chief officer orders the helmsman to completely drain the left and right ballast tank three. As the head of daily work, he then instructs the bosun to prepare the tools and materials to be used, which are placed inside the tank. During the ballast discharge, if the right ballast 3 is empty, the discharge pipe is closed, and a little water is left in the left ballast 3 to extinguish tiny sparks from using the electric welding machine. Lights are installed inside the ballast tank for illumination, and a blower is placed at the manhole entrance to regulate air circulation. The Chief Officer, Bosun, and the pump man enter the tank to locate the leak, bringing a flashlight, putty, hammer, rubber packing, iron plate, and spanner.

Once the leak location is found, it is patched with putty. The Chief Officer, who has exited the tank, orders a mixture of cement, sand, and caustic soda to be prepared, evenly mixed with water, and stirred until smooth. After stirring, the cement mixture is lifted into the tank using a bucket. The mixture is then placed on the leaking plate and pressed with rubber packing to prevent further seepage, and the surrounding area is dried. A mold is then made using a new iron plate, adjusted to the length and width of the leaking plate section. This new iron plate is pressed over the rubber packing and welded around its edges using an electric welding machine by the bosun and pump man after the left ballast plate no. three are welded using an electric welding machine, the water in

the ballast tank no. three is pumped out, and the area around the leak is cleaned with a scraper and dried. The prepared cement mixture in the bucket is then poured around the edges of the newly welded plate to reinforce the patch. The mixture is monitored until it hardens, after which an aqua sealer is applied over the cement mixture around the edges of the newly welded plate. Thus, the leak patching is completed, and the manhole can be closed again. The patching using this technique is strong enough to last for several months.

Regular and Timely Docking

According to the latest regulation by the Director General of Marine Affairs No. HK.103/1/4/DJPL-14 regarding the docking (dry-docking) of Red-White flagged vessels. This new regulation was signed by the Director General of Marine Affairs, Capt. Bobby Mamahit, on January 30, 2014. The regulation consists of Chapter V and 14 articles, which state that passenger ships must undergo inspection or docking every year, similar to the previous regulation. However, the docking rules for ships other than passenger ships are categorized into two categories. For Class A90 ships, fuel docking is mandatory every four years, while intermediate docking is required every two years. Thus, in conclusion, Red-White flagged ships must dock every two years. For Class A100 ships, a mandatory fuel docking survey is required every five years, while an intermediate survey must be conducted between the 2nd and 3rd year. In conclusion, Class A100 ships must dock every 2.5 years.

Table 2. Survey Schedule

Ship Category	Type of Survey	Frequency	Conclusion
Passenger Ships	Inspection/Docking	Every year	Must dock every year
A90	Fuel Docking	Every 4 years	Must dock every 4 years
	Intermediate Docking	Every 2 years	Must dock every 2 years
A100	Fuel Docking Survey	Every 5 years	Must dock every 5 years
	Intermediate Survey	Between 2nd and 3rd year	Must dock every 2.5 years

Source: Primary Data (2024)

With regular docking schedules, maintenance and repairs to prevent more severe ship damage can be anticipated early, so handling them does not require more time and cost.

Source: Primary Data (2024)

Figure 5. Welding Results

Leaks in a ship's ballast tank are a serious issue that can disrupt ship operations and potentially have significant environmental impacts (Fontes et al., 2023; Leivestad, 2021; Sezer et al., 2022). In

this study, the primary focus is to identify the causes of ballast tank leaks and the patching techniques used to address leaks in the ballast and cargo tanks of the MT. Sepinggan ship. Based on observations, several factors are causing leaks in the MT. Sepinggan's ballast tank was identified. The first factor is the company's delay in docking its fleet. The MT. Sepinggan last underwent docking in 2012, and based on the CAS (Condition Assessment Scheme) certificate. It should have been docked again in June 2015. However, this still needs to be done, making the ballast tank plates thin and prone to leaks. The second factor is limited funding and inconsistent operating routes of ships, which result in irregular docking and specialized maintenance schedules. For example, the MT. Sepinggan's operational route covers areas with high traffic and rough seas, causing stress and wear on the ballast tanks, thereby increasing the risk of leakage. In contrast, ships operating in calmer waters with more regular maintenance schedules tend to have better ballast management and fewer problems. Comparing these conditions highlights the importance of timely docking and maintenance in preventing ballast tank leaks. The irregular routes and delayed maintenance of the MT. Sepinggan underscore the importance of consistent docking schedules and adequate funding to ensure the integrity of the ship's ballast tanks.

Theoretically, ballast tank leaks can be caused by various factors, such as corrosion, structural damage, and material wear. Corrosion, in particular, is a primary cause of ballast tank leaks. Iron and steel, the main materials in shipbuilding, rust quickly when exposed to air and water simultaneously. Therefore, regular maintenance and inspection of ballast tank plates are crucial to preventing leaks. The patching technique is used to address leaks in the MT. Sepinggan's ballast tank involves several steps, from identifying the leak location, preparing materials, and equipment, to executing the patch using new iron plates (Rohde et al., 2020). This technique is effective for temporary leak handling, but comprehensive repairs and plate replacements are needed for a long-term solution. Previous research indicates that ballast tank leaks often result from a lack of maintenance and routine inspections (Davidson et al., 2021). External factors, such as marine environmental conditions, hydrostatic pressure, and ship operational loads, can also affect the structural integrity of ballast tanks (Abbas & Shafiee, 2020; Ozguc, 2020). Hence, ship operators must ensure their ships undergo regular docking and maintenance.

Regarding the MT. Sepinggan, the delayed docking and lack of maintenance are the primary causes of the leaks. This aligns with theories and previous research emphasizing the importance of regular maintenance in maintaining a ship's structural integrity (C. Song & Cui, 2020). This study also highlights the importance of having an educated and experienced crew to handle potential ship issues, including ballast tank leaks. In conclusion, shipping companies must ensure their ships undergo regular docking and maintenance to prevent ballast tank leaks. Additionally, companies should ensure their crew possesses the necessary knowledge and skills to handle potential ship issues. This way, the risk of ballast tank leaks can be minimized, ensuring smooth and safe ship operations.

CONCLUSION AND SUGGESTION

Conclusion

This research successfully analyzed the causes of ballast tank leaks on the MT. Sepinggan vessel and identified docking delays as the main factor. These delays lead to the thinning of tank plates, making them prone to leaks. Other contributing factors include limited funds and the uncertainty of the vessel's operational routes, resulting in irregular maintenance schedules. The research also applied repair techniques through technical procedures using new iron plates, which proved effective for temporarily handling leaks. Additionally, the importance of regular maintenance and timely docking was emphasized as part of ship management strategies to prevent further damage and ensure the safety and smooth operation of the vessel. Good maintenance practices, including planned maintenance and plate replacement, are crucial in maintaining the ship's structural integrity. The research also highlighted the importance of having a well-educated and experienced crew to handle leaks quickly and appropriately. Implementing maintenance practices that include technical patch procedures and timely docking can minimize the risk of ballast tank leaks, ensuring the vessel's operations remain safe and efficient.

Suggestion

Suggestions for this research include the following: shipping companies should strictly adhere to the established docking schedules for their vessels to prevent damage and leaks that could affect the operational and safety aspects of the ships. Additionally, it is recommended to increase budget allocation and improve operational management to ensure that ship maintenance and repairs are conducted in a timely and thorough manner. Further research could focus on the development of advanced monitoring technology and the early detection of ballast tank leaks, as well as the evaluation of more efficient and durable repair methods. Moreover, the training and skill enhancement of crew members should be prioritized to ensure they have the necessary capabilities to handle leaks and other issues on board. Future research could also explore the environmental impact of ballast tank leaks and develop environmentally friendly solutions to address them.

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