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Analysis of Tank Cleaning Implementation Using Crude Oil Washing on MT. Swordfish

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ABSTRACT

The implementation of Crude Oil Washing (COW) in the tank cleaning process on board the MT Swordfish still faces various technical and operational challenges, even though this method is considered more effective and environmentally friendly because it uses crude oil as a cleaning medium. This study aims to analyze the obstacles that arise in the implementation of COW and evaluate the efforts made to overcome these obstacles. This study uses a qualitative descriptive method with data collection techniques in the form of observation, interviews, and documentation. Data analysis was carried out through the stages of data reduction, data presentation, and conclusion drawing, while data validity was ensured through triangulation techniques. The results of the study show that the implementation of COW faces several major obstacles, both technical and non-technical. Technically, the problems found include leaks in the COW pipe due to corrosion, disturbances in the Butterworth automatic system, and rust accumulation on the purging pipe and manhole components. Non-technical obstacles included the crew's limited understanding of COW procedures and work fatigue caused by insufficient personnel. To overcome these problems, various efforts were made, including equipment repairs and routine maintenance, improving the crew's understanding through briefing activities, and adjusting the task distribution system. Based on these findings, it can be concluded that the success of COW implementation is highly dependent on the condition of the equipment and the competence of the crew. Therefore, planned maintenance and continuous training are needed to improve efficiency, safety, and environmental sustainability in tank cleaning activities.

Keywords: *Crude Oil Washing, Tank Cleaning, Operational Problems, Ship Maintenance, Crew Competence.*

ABSTRAK

Penerapan Crude Oil Washing (COW) dalam proses pembersihan tangki di atas kapal MT *Swordfish* masih menghadapi berbagai kendala teknis dan operasional, meskipun metode ini dinilai lebih efektif dan ramah lingkungan karena menggunakan minyak mentah sebagai media pembersih. Penelitian ini bertujuan untuk menganalisis hambatan yang muncul dalam pelaksanaan COW serta mengevaluasi upaya yang dilakukan untuk mengatasinya. Penelitian ini menggunakan metode deskriptif kualitatif dengan teknik pengumpulan data berupa observasi, wawancara, dan dokumentasi. Analisis data dilakukan melalui tahapan reduksi data, penyajian data, dan penarikan kesimpulan, sedangkan keabsahan data dijamin melalui teknik triangulasi. Hasil penelitian menunjukkan bahwa pelaksanaan COW menghadapi beberapa kendala utama, baik yang bersifat teknis maupun nonteknis. Secara teknis, permasalahan yang ditemukan meliputi kebocoran pada pipa COW akibat korosi, gangguan pada sistem otomatis Butterworth, serta penumpukan karat pada pipa purging dan komponen manhole. Sementara itu, kendala nonteknis meliputi keterbatasan pemahaman awak kapal terhadap prosedur COW serta kelelahan kerja akibat jumlah personel yang tidak memadai. Untuk mengatasi permasalahan tersebut, berbagai upaya telah dilakukan, antara lain perbaikan peralatan dan pemeliharaan rutin, peningkatan pemahaman awak kapal melalui kegiatan briefing, serta penyesuaian sistem pembagian tugas. Berdasarkan temuan tersebut, dapat disimpulkan bahwa keberhasilan penerapan COW sangat bergantung pada kondisi peralatan dan kompetensi awak kapal. Oleh karena itu, diperlukan pemeliharaan terencana dan pelatihan berkelanjutan guna meningkatkan efisiensi, keselamatan, dan keberlanjutan lingkungan dalam kegiatan pembersihan tangki.

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Kata kunci: *Crude Oil Washing (COW), Pembersihan Tangki, Kendala Operasional, Pemeliharaan Kapal, Kompetensi Awak Kapal.*

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1. INTRODUCTION

Ships as a mode of maritime transportation require special care to ensure that they remain seaworthy and can operate properly at all times. To ensure that

ships are always ready for sea, routine maintenance is necessary. Regular inspection and repair of engines and important ship parts are essential to minimize and detect damage to engines, decks, and navigation equipment (Park & Lee, 2025). In maintenance, cleaning the ship is also very important for the condition of the ship. Cleaning can be done routinely, including cleaning the engine, deck, accommodation, and bridge. In this study, cleaning was more focused on cleaning the cargo tanks before the MT Swordfish entered the docking process.

The tank cleaning process is carried out to remove any remaining cargo or sludge that is still attached to the walls and bottom of the cargo tanks to ensure the cleanliness of the tanks and their readiness for the next loading or to enter the docking process (Hasan et al., 2024). If the cargo tanks are not cleaned optimally, crude oil sludge residue can remain, causing a decline in cargo quality, crosscontamination, negative impacts on safety and the environment, and potential disruptions to the docking process (Adigawe et al., 2022). Therefore, the application of efficient and effective tank cleaning methods is very important to maintain the cleanliness of cargo tanks and the operational readiness of ships. One method commonly used on crude oil tankers is Crude Oil Washing (COW) (Maes, 2025), which is a cleaning method that utilizes crude oil itself as a cleaning medium by heating it, recirculating it, and spraying it onto the tank wall surface using special equipment such as a Butterworth machine (Maljković et al., 2022).

Crude Oil Washing (COW) is a process used primarily in the maritime industry to clean the cargo tanks of oil tankers. This method involves using the crude oil itself to wash the tanks, which helps in reducing the amount of residual oil left in the tanks after unloading. Petroleum refining involves various systematic techniques to remove contaminants and improve the quality of the final product. One of the main methods is water washing, which dissolves inorganic impurities through a series of separation stages using API and flotation systems, solid sediment separation, and finally reverse osmosis as the final purification process (Cruz Pedrero Sr. et al., 2005; Manuel Sr. et al., 2005). This process is closely related to desalting, a crucial step to remove inorganic salts, suspended solids, and heavy metals dissolved in water. In the desalting stage, the oil is mixed with washing water and a demulsifier chemical, then exposed to an electrostatic field to break down the emulsion so that the water and oil are completely separated (Pak & Mohammadi, 2008). In addition

to crude oil processing, there is also a chemical hot washing method specifically used to treat oily sludge. This technique utilizes compound detergents with strict control of temperature, pH, and stirring speed parameters to ensure that the oil content in the waste is significantly and optimally reduced (Yan et al., 2024).

The COW method is very effective in dissolving and removing crude oil residues that are difficult to clean with water (Gao et al., 2021; Hernandez et al., 2019; M. Wang et al., 2019), thereby speeding up the cleaning process and reducing hazardous waste (Bao et al., 2022; Tian et al., 2024; Y. Wang et al., 2022). Although COW is recognized as an efficient and environmentally friendly tank cleaning method, its application in the field is not without various technical obstacles. One of the primary issues with COW is the blockage of piping systems caused by oil residues that are not fully dissolved. This can significantly hinder the cleaning process and reduce the efficiency of the system (Chrysalidis & George, 2020). To address this, it is essential to enhance the mechanical interactions during the cleaning process. Techniques such as bubbling, pulsation, and cavitation have been shown to improve cleaning efficiency by intensifying mechanical interactions, thereby reducing the cleaning time and the concentration of cleaning agents required (Maziarz et al., 2026). In addition, damage to key equipment such as the Butterworth machine can also occur, slowing down the cleaning process and disrupting the ship's overall operational schedule (International Maritime Organization, 2017, MARPOL Consolidated Edition 2017, IMO Publishing).

The evolution of Crude Oil Washing (COW) and tank maintenance has led to the integration of sophisticated equipment and supporting systems designed to optimize efficiency and safety. At the forefront of these innovations are automated systems like the BLABO system, which facilitates non-man entry cleaning by integrating desludging and oil separation within a single process, potentially reducing downtime by up to 80% (Schindler & Suba, 2009; Wetlesen, 2006). To ensure safety, these systems often operate under inert gas blanketing to mitigate explosion risks (Wetlesen, 2006). Complementing these are high-impact cleaning methods, such as Cleaning in Place (CIP) systems, which utilize solid stream nozzles at pressures reaching 1,000 psi to dislodge stubborn residues without requiring equipment disassembly (Pagcatipunan, 2003).

Beyond automation, mechanical and chemical methodologies play a vital role in residue management. General mechanical cleaning remains a staple due to its cost-effectiveness and environmental advantages (Di et al., 2014), while specialized SOTU technology enhances the utilization value of waste oil by effectively separating oil, water, and solids (Su et al., 2023).

Supporting these physical tools are chemical cleaning agents that utilize solvents and heat to remove organic fouling and hazardous pyrophoric iron sulfide deposits (Otzisk, 2008). Collectively, these modern advancements, such as those implemented at the MOL refinery, represent a shift toward prioritizing health, safety, and environmental sustainability while maximizing the economic recovery of oil (Schindler & Suba, 2009; Su et al., 2023; Wetlesen, 2006).

The effectiveness of tank cleaning using the COW method is highly dependent on several key factors, namely the implementation of standard operating procedures, the technical condition of the equipment used, and the level of competence of the ship's crew in carrying out the cleaning process. If one of these aspects is not adequately fulfilled, the tank cleaning process will not run optimally and may even pose additional risks, such as incomplete cleaning or more serious equipment damage (ISGOTT, 2006, International Safety Guide for Oil Tankers and Terminals 5th edition, International Chamber of Shipping). Therefore, the successful implementation of tank cleaning using COW requires careful planning, regular equipment maintenance, and ongoing training for the crew so that the procedures can be carried out in accordance with the safety and efficiency standards set out in international maritime regulations. The tank cleaning process using the COW method has several advantages, including minimizing the potential for contamination during tank cleaning activities, reducing dependence on manual labor in removing sludge from tanks, reducing the time and costs required for both routine tank cleaning and docking activities, and reducing the level of corrosion on the inner surface of the tank.

Based on research conducted on the MT Swordfish, various obstacles were found that affected the effectiveness of the tank cleaning process using the COW method before the ship entered the dockyard. Some of the problems encountered included suboptimal equipment maintenance and a low level of understanding among the crew regarding the operation of the COW system. These conditions

caused the cleaning process to not run optimally and resulted in increased crew working hours, which in turn had the potential to delay the completion of other tasks on board the ship. Based on this, this study aims to analyze the obstacles that arise in the implementation of COW and evaluate the efforts made to overcome these obstacles.

2. METHODS

This study uses a qualitative descriptive method that aims to describe and understand phenomena based on actual conditions in the field without making comparisons or testing relationships between variables (Sugiyono, 2020). The study was conducted on the MT Swordfish ship from November 2, 2023, to November 15, 2024. The data sources in this study consisted of primary and secondary data.
Primary data was obtained through observation of tank cleaning activities carried out on board the MT. Swordfish, as well as through interviews with several ship officers, namely the Chief Officer, Second Officer, Third Officer, Pumpman/Boatswain, and Able Seaman, in order to identify the obstacles encountered and the efforts made to optimize the tank cleaning process. Meanwhile, secondary data was obtained from relevant books and internal ship documents, such as reports, archives, activity records, and other documents related to the research topic.

Data collection in this study was carried out through observation, interviews, and documentation techniques using primary and secondary data sources (Sugiyono, 2020). Observations were conducted participatively, whereby the researcher was directly involved in the activities being observed, particularly during the tank cleaning process using the Crude Oil Washing (COW) method on board the MT Swordfish, so that the data obtained truly reflected the actual conditions in the field. Structured interviews were conducted face-to-face with informants directly involved in the tank cleaning process, namely the Chief Officer, Second Officer, Third Officer, Pumpman/Boatswain, and Able Seaman, to obtain information related to the obstacles encountered and the efforts made to optimize the application of COW. In addition, documentation was used as supporting data obtained from ship manuals, reports, archives, photos of operational activities, and sea practice logs related to the tank cleaning process and maintenance of supporting equipment.

Data analysis in this study used the Miles and Huberman model, which includes the stages of data reduction, data presentation, and conclusion drawing (Sugiyono, 2020). Data reduction was carried out by simplifying and focusing the field data to identify relevant themes and patterns. Furthermore, the data was presented in the form of descriptive narratives to facilitate understanding before drawing conclusions in a gradual and contextual manner. To ensure data validity, this study applied triangulation techniques, both technical triangulation and source triangulation, by comparing the results of observations, interviews, and documentation from various informants and data sources (Sugiyono, 2020). The application of triangulation aims to increase data credibility and ensure that the research findings truly reflect the actual conditions in the field.

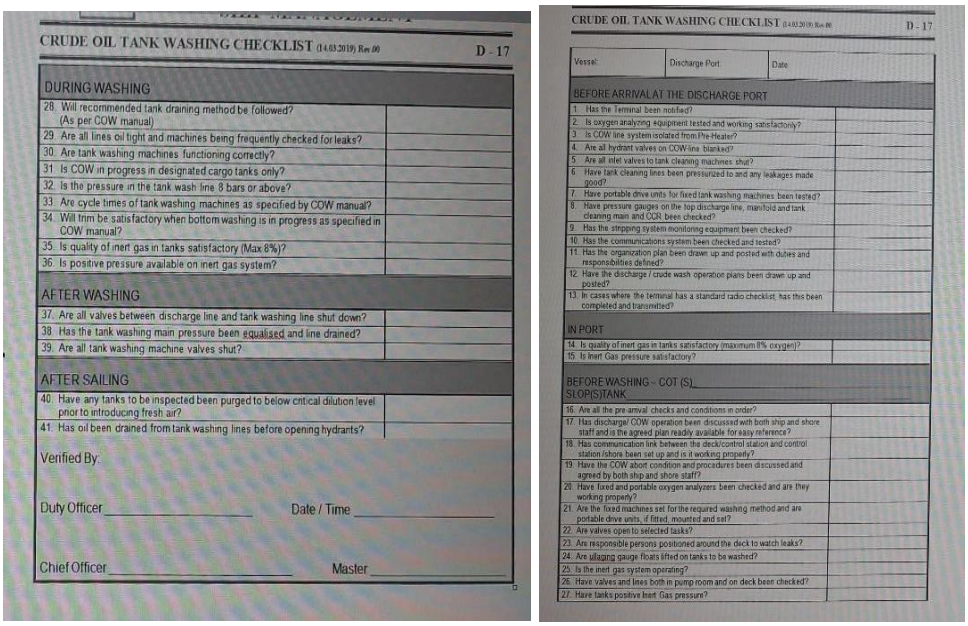
3. RESULT AND DISCUSSION

MT. Swordfish is a crude oil tanker owned by PT Swordfish Maritime Pte Ltd, headquartered at Danatama Square, Jalan Mega Kuningan Timur Blok C6 Kavling 12, Setiabudi, South Jakarta, DKI Jakarta. The ship was built on August 2, 2003, in Mokpo, South Korea, by Hyundai Samho Heavy Industries Co. Ltd. MT. Swordfish is registered under the Marshall Islands flag with IMO number 9248849, call sign V7A7232, and MMSI 538010671. MT Swordfish has an overall length (LOA) of 250.17 meters, a width of 44 meters, and a gross tonnage (GT) of 62,371. The ship is powered by a Hyundai B&W 7S60MC main engine and is equipped with 14 tanks, consisting of 12 cargo tanks and 2 slop tanks.

Figure 1. MT. Swordfish

During the loading and unloading of crude oil on tankers, there are often residual deposits or sludge that remain attached to the walls and bottom of the cargo

tanks after unloading is complete. This condition can hinder the performance of the cargo pumps, reduce the effective capacity of the tanks, and decrease the efficiency of subsequent loading processes. If this condition persists over several voyages, residual oil can accumulate to the point of covering the suction pipe or bell mouth at the bottom of the tank, thereby obstructing the flow of oil during both loading and unloading. On the MT Swordfish, the last thorough tank cleaning was carried out in 2023. During the study, the ship was scheduled to enter dry dock in May 2024, so it was necessary to carry out a thorough tank cleaning beforehand to ensure the ship's operational readiness and compliance with applicable safety regulations. Therefore, during the five-day voyage from Khawr Fakkan to Dubai, MT Swordfish carried out tank cleaning using the Crude Oil Washing (COW) method by circulating part of the crude oil cargo through special tank cleaning equipment. This process aims to effectively dissolve, loosen, and remove oil residues so that the cargo tanks are ready for inspection, maintenance, and subsequently enter the dry docking process safely.



CRUDE OIL TANK WASHING CHECKLIST (14.03.2019) Rev.00 D - 17

DURING WASHING	
28. Will recommended tank draining method be followed? (As per COW manual)	
29. Are all lines oil tight and machines being frequently checked for leaks?	
30. Are tank washing machines functioning correctly?	
31. Is COW in progress in designated cargo tanks only?	
32. Is the pressure in the tank wash line 8 bars or above?	
33. Are cycle times of tank washing machines as specified by COW manual?	
34. Will trim be satisfactory when bottom washing is in progress as specified in COW manual?	
35. Is quality of inert gas in tanks satisfactory (Max 8%)?	
36. Is positive pressure available on inert gas system?	
AFTER WASHING	
37. Are all valves between discharge line and tank washing line shut down?	
38. Has the tank washing main pressure been equalised and line drained?	
39. Are all tank washing machine valves shut?	
AFTER SAILING	
40. Have any tanks to be inspected been purged to below critical dilution level prior to introducing fresh air?	
41. Has oil been drained from tank washing lines before opening hydrants?	

Verified By:

Duty Officer _____ Date / Time _____

Chief Officer _____ Master _____

CRUDE OIL TANK WASHING CHECKLIST (14.03.2019) Rev.00 D - 17

Vessel: Discharge Port: Date:

BEFORE ARRIVAL AT THE DISCHARGE PORT	
1. Has the Terminal been notified?	
2. Is oxygen analyzing equipment tested and working satisfactorily?	
3. Is COW line system isolated from Pre-Heater?	
4. Are all hydrant valves on COW line blanked?	
5. Are all inlet valves to tank cleaning machines shut?	
6. Have tank cleaning lines been pressurized to and any leakages made good?	
7. Have portable drive units for fixed tank washing machines been tested?	
8. Have pressure gauges on the top discharge line, manifold and tank cleaning main and CCR been checked?	
9. Has the stripping system monitoring equipment been checked?	
10. Has the communications system been checked and tested?	
11. Has the organization plan been drawn up and posted with duties and responsibilities defined?	
12. Have the discharge / crude wash operation plans been drawn up and posted?	
13. In cases where the terminal has a standard radio checklist, has this been completed and transmitted?	
IN PORT	
14. Is quality of inert gas in tanks satisfactory (maximum 8% oxygen)?	
15. Is Inert Gas pressure satisfactory?	
BEFORE WASHING – COT (S)_____ SLOP(S)TANK_____	
16. Are all the pre-arrival checks and conditions in order?	
17. Has discharge/ COW operation been discussed with both ship and shore staff and is the agreed plan readily available for easy reference?	
18. Has communication link between the deck/control station and control station /shore been set up and is it working properly?	
19. Have the COW abort condition and procedures been discussed and agreed by both ship and shore staff?	
20. Have fixed and portable oxygen analyzers been checked and are they working properly?	
21. Are the fixed machines set for the required washing method and are portable drive units, if fitted, mounted and set?	
22. Are valves open to selected tanks?	
23. Are responsible persons positioned around the deck to watch leaks?	
24. Are ullaging gauge floats lifted on tanks to be washed?	
25. Is the inert gas system operating?	
26. Have valves and lines both in pump room and on deck been checked?	
27. Have tanks positive Inert Gas pressure?	

Figure 2. Crude Oil Washing Checklist

Based on observations and interviews, one of the main obstacles encountered during tank cleaning using the COW method on board the MT Swordfish was a leak in the right COW line number 4 during the cleaning process of the port and starboard 4-sided cargo tanks. This incident caused an eight-hour delay in operations and had the potential to cause environmental hazards. Observations

showed that the pumpman regulated the flow (line-up) from the cargo pump to the tank cleaning heater, then channeled it to the COW line on deck and sprayed it into the tank using a fixed butterworth machine with a capacity of 90 m^3/hour at a pressure of 10 bar.

Interviews with the Chief Officer, Second Officer, Third Officer, Pumpman, and Able Seaman (C) confirmed that the leak was caused by old, rarely used pipes that lacked maintenance and had corroded due to exposure to seawater, rendering them unable to withstand the pressure of the crude oil flow. The Chief Officer explained that the leak occurred at the bottom of the pipe, which had been eroded by rust, while the Second Officer added that the pressure from the cargo pump exacerbated the condition of the pipe. The Third Officer, Pumpman, and Able Seaman (C) also confirmed that the age of the pipe and the level of corrosion were the main causes of the leak.

To address the problem, the crew temporarily stopped the tank cleaning process, secured the oil spill in accordance with the Shipboard Oil Pollution Emergency Plan (SOPEP) procedures, and made temporary repairs by patching the leaking section of the pipe with steel plates through welding carried out by the Boatswain with the assistance of the Fitter on the instructions of the Chief Officer. With these temporary repairs, the COW process on the starboard side tank 4 could be resumed, while a complete pipe replacement is planned to be carried out when the ship enters dry dock.

Figure 3. Repaired COW Line Pipe

In addition, another obstacle was the malfunctioning of several fixed butterworth machines. Based on observations and interviews, it was found that during the tank cleaning using the COW method on board the MT Swordfish, several

fixed butterworth machines were unable to move automatically, particularly on the port side 1 tank, port side 3 tank, and starboard side 6 tank. This condition was caused by rust buildup on the gears due to lack of maintenance and infrequent use of tank cleaning equipment, resulting in a jam in the water jet drive mechanism.

To overcome this problem, the crew, under the instructions of the Chief Officer, inspected the gears, lubricated them with grease, and operated the butterworth machine manually using a ring spanner until the equipment could function temporarily. This action ensured that the tank cleaning process could continue to run effectively, while the problematic equipment was marked for replacement when the ship entered dry dock. Additionally, during the inspection process, the crew discovered slight wear on the gear teeth, indicating the need for preventive maintenance and emphasizing the importance of regular equipment inspection and operation to prevent similar operational delays in future tank cleaning procedures.

Figure 4. Butterworth Machine

In addition, researchers also found rust on the wheel thread of the manhole cover and on the butterfly purging pipe valve thread. Based on observations and interviews, researchers found obstacles in the gas freeing stage of the tank cleaning process on the MT Swordfish, namely difficulties in opening the cargo tank manhole cover and purging pipe due to rust on the wheel threads and butterfly valve threads. This condition caused the threads to jam, so that the process of opening the manhole and purging pipe took longer and resulted in a delay in the gas freeing process for several hours. The rust was caused by a lack of maintenance of the tank cleaning support equipment and the influence of external factors, such as exposure to seawater and rainwater. To overcome this obstacle, on the instructions of the

Chief Officer, the crew cleaned the rust using a wire brush and WD-40 liquid, then lubricated the threads with grease. Next, the purging pipe was forcibly opened using an iron rod, while the manhole cover was opened with the help of a tackle so that the wheel could rotate. Although the gas freeing process was delayed, these efforts successfully overcame the obstacles so that the next operational stages could still be carried out.

Figure 5. Condition of Rusty Manhole Threads

Tank cleaning is the process of cleaning cargo tanks of any residue from previous cargoes, whether liquid, sludge, or gas, with the aim of ensuring that cargo tanks are clean and ready for use for the next cargo without contamination from previous cargoes (Salo et al., 2005). Tank cleaning plays a very important role in tanker operations, both in maintaining cargo quality, ensuring the safety of the crew, protecting the environment, and supporting ship maintenance activities (Imran et al., 2022). Based on the results of the study, several obstacles and efforts to overcome them were found:

1. Leakage on the starboard side of COW line number 4

   The leakage on the starboard side of COW line number 4 occurred due to the aging of the pipe, exposure to seawater, and corrosion, which rendered it unable to withstand the pressure of the crude oil flow. This condition caused a delay in the tank cleaning process for several hours and had the potential to cause environmental pollution. To address this issue, the crew temporarily halted operations, secured the oil spill in accordance with SOPEP procedures, and made temporary repairs by patching the leaking section of the pipe with steel plates using welding. This action allowed the tank cleaning process to continue safely while awaiting permanent pipe replacement when the ship entered dry dock.

2. Fixed Butterworth engines did not move automatically

Several fixed Butterworth engines cannot move automatically due to corrosion on the gears caused by lack of maintenance and infrequent use of tank cleaning equipment. This condition reduces the effectiveness of spraying and has the potential to slow down the cargo tank cleaning process. As a countermeasure, the crew cleans the rust on the gears, lubricates them with grease, and operates the engine manually using a ring spanner.

Although this is only a temporary measure and movement is limited, it allows the tank cleaning process to continue until repairs or permanent component replacement is carried out when the ship enters dry dock.

3. Rust on manhole threads and butterfly purging pipe valves

   Rust on the threads of the manhole wheel and butterfly valve purging pipe caused difficulties in the opening process, slowing down the gas freeing stage. This problem was caused by a lack of maintenance and continuous exposure to seawater and rainwater. To overcome this, the crew cleaned the rust and lubricated the threads, then opened the components manually with the help of additional tools such as iron rods and hook tackle. Although it required more time and effort, these efforts successfully enabled the gas freeing process to continue, while emphasizing the importance of routine maintenance and inspection of tank cleaning support equipment.

The COW procedure on board the MT Swordfish was carried out before the ship entered dry dock, after the completion of deslopping and demucking of the cargo tanks at Khawr Fakkan with the assistance of shore personnel. The purpose of this activity was to manually clean the inside of the tanks of cargo residue and sludge. Prior to deslopping and demucking, a gas check was performed using a multi-gas detector to ensure that the atmospheric conditions inside the tanks were safe for the crew to enter. Tank cleaning is a very important activity for the safety of the crew, as cargo residues or sludge that are flammable or toxic can cause explosions or poisoning (Chrysalidis & George, 2020). Therefore, strict safety procedures are essential during the tank cleaning process, including mandatory tank atmosphere checks before personnel work inside (Altun & Arslan, 2013). After these initial stages, the implementation of tank cleaning using the COW method requires careful planning, crew training, and the readiness of supporting equipment so that

the process can run safely, systematically, and in accordance with the safety standards and regulations set by the IMO.

The COW process on board the MT Swordfish was carried out during the voyage from Khawr Fakkan to Dubai through several stages, namely tank heating, inerting, gas freeing, crude oil washing, deslopping, and demucking. This process was supported by key equipment, including a fixed butterworth machine, an inert gas system, a cargo pump, and a stripping pump. In addition, the stability of the ship was maintained through ballast adjustment during the activity. With the implementation of proper procedures, supervision by the Chief Officer, and good coordination among the crew, the COW was carried out effectively to remove residual cargo, ensure tank cleanliness, and prepare the ship for inspection or dry docking safely and optimally.

4. CONCLUSION

Based on the research objectives, it can be concluded that the implementation of tank cleaning using the Crude Oil Washing (COW) method at MT. Swordfish has not been optimal due to several major obstacles, namely leaks in the crude oil washing line due to corrosion, suboptimal performance of the fixed butterworth machine due to inadequate maintenance, and operational obstacles due to corrosion on the purging pipe and manhole threads. These obstacles indicate that equipment maintenance and crew readiness play an important role in supporting the smooth running of the tank cleaning process. Efforts such as temporary repairs, routine equipment maintenance, work schedule arrangements, and improving crew understanding have been able to maintain the continuity of operations, even though conditions are not yet ideal. Therefore, this study recommends the implementation of routine and continuous equipment maintenance, improved maintenance discipline even when equipment is rarely used, and effective work time management with the full involvement of the crew under the supervision of the Chief Officer, so that tank cleaning in the future can be carried out more effectively, safely, and efficiently.

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