OPTIMIZATION OF MAIN ENGINE COOLING SYSTEM MAINTENANCE FOR MITSUBISHI 6UEC52LS ON MT. PRINCESS NAOMI

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ABSTRACT

The purpose of the study is to optimize the cooling system maintenance on the Mitsubishi 6UEC52LS Main Engine on the MT. Princess Naomi that belongs to PT. Waruna Nusa Sentana. This research was conducted in the engine room of the MT. Princess Naomi. This research employed qualitative descriptive approach methods. Data collection techniques were obtained through field research by combining observation methods, documentation, in-depth interviews, and literature review. Data analysis was conducted in triangulation (combination). The results of the study showed that the maintenance of the diesel engine cooling system on the MT. Princess Naomi that belongs to PT. Waruna Nusa Sentana has been running optimally with an average after optimization treatment of 83.75%. The cooling system on the main engine of the MT. Princess Naomi applied a closed cooling system. Parts of the cooling system treated include: an expansion tank, centrifugal pump, fresh water cooler, and sea chest..

Kata kunci : *cooling system, maintenance, main engine*.

INTRODUCTION

The diesel engine was invented by Rudolf Christian Karl Diesel, who was born on March 18, 1858, in Paris. Diesel engines are also used as the main propulsion system on ships. The presence of diesel engines on board is crucial, as their operation ensures the smooth running of maritime activities.[1]. The ship's main propulsion engine must be able to operate continuously during its operation. To support its performance, several essential systems are required. These include the cooling system and the lubrication system, which function to dissipate heat from the engine[2]. During engine combustion, these systems must be properly maintained to ensure optimal performance and prevent disruptions [3]. Proper maintenance of the lubrication system, fuel system, and cooling system by skilled professionals can extend the lifespan of main engine components, reduce high operational costs, prevent severe damage, and minimize operational disruptions [4][5]. In the operation of a ship's engine, without a proper cooling system, the engine will quickly suffer damage due to overheating or excessive heat. Therefore, the maintenance of the cooling system in the main engine is essential and must be carried out according to the operational procedures outlined in the manual book. To ensure that the diesel engine can operate continuously, safely, and with durability, the heat absorbed by its components, such as the cylinder liner, cylinder head, and exhaust valve, must be transferred to a cooling fluid. There are several options for cooling systems, but for ship diesel engines, freshwater is chosen as the cooling medium due to its lower corrosiveness and better temperature control compared to seawater. In other words, as long as a diesel engine is operating, it requires cooling. An open cooling system is a type of diesel engine cooling system that uses seawater directly as the cooling medium[6]. Seawater cooling is an open cooling system because the coolant is directly exposed to the external environment through seawater, which cools the cooling water, lubricating oil, air, and turbocharger within the cooling system. In this process, seawater directly cools the diesel engine[7]. The open cooling system has both advantages and disadvantages. Its advantages include a relatively simple design that does not require an expansion tank, making it more cost-effective and the continuous availability of seawater as a cooling medium. However, it also has several drawbacks, such as the formation of salt deposits at temperatures above 50°C, which can clog pipelines, a high risk of corrosion that accelerates engine wear, and difficulties in regulating seawater temperature in cold regions, where extremely low temperatures may cause the cylinder liner to crack due to significant temperature differences[8]. Meanwhile, the closed cooling system cools the diesel engine using liquid coolant or fresh water, which is then cooled by seawater in a cooler. The cylinder jacket cooling system operates in a closed-loop flow, where after cooling the jacket, the coolant directly flows to other engine components, such as the cylinder cover and exhaust valve. To maintain adequate coolant pressure, the cooling water flow must remain full from the main tank[9].

The coolant temperature is regulated by controlling the flow of water through the cooler, which is adjusted by opening the bypass valve. The amount of freshwater flowing must remain constant, and if the coolant temperature is too low, it must be increased to the predetermined temperature by injecting hot steam into the cooling water pipes before the engine is started [10]. To increase the coolant temperature before starting the engine, this method is commonly used in cold regions such as European countries. However, in Indonesia, it is rarely used since the coolant temperature already meets the required standards. The advantages of a closed cooling system include (1) using fresh water as a coolant reduces or prevents corrosion risks, and (2) controlling the inlet and outlet coolant temperature is easier through the cooler. However, there are some disadvantages, such as (1) dependency on the availability of freshwater coolant, (2) a more expensive piping system due to the need for a cooler, expansion tank, and additional piping, and (3) the complexity of the cooling system in ships, as it consists of interconnected pipes, pumps, and coolers. This system often becomes intricate since both the main diesel engine and auxiliary engines, along with various auxiliary equipment, are connected to it [11] [3]. The cooling system for diesel engines primarily involves freshwater circulation, where the entire system consists of a seawater section outside the ship's hull and a freshwater section[12]. Inside the engine, the heat absorbed by the fresh water in a closed circuit is then transferred to seawater in the cooler. The amount of coolant must be sufficient to ensure that in tropical seawater conditions, the discharge temperature does not exceed normal limits. The flow of cooling water can be regulated using a control valve, which is crucial to maintaining the correct engine load. The temperature of the cooling water after heat exchange must not be too low, as previously discussed, and it is often maintained automatically at a specific value[13].

After undergoing these cooling processes, seawater is discharged through a discharge valve. By recirculating part of the heated cooling water through this valve, the coolant temperature entering the cooler can be maintained at the minimum level specified in the manual book. In a water cooling system for diesel engines, several issues often arise, such as fluctuations in coolant temperature, pressure instability, and temperature blockages, which require corrective measures on some or all cylinders. Other operational issues must also be quickly identified to determine their root causes. During field observations on the Mitsubishi 6UEC52LS main engine of MT. Princess Naomi, only 45% of the procedures were carried out according to the manual book, indicating that some systems were not functioning optimally. This highlights the need for more intensive maintenance actions [14]. The objective of this study is to optimize the closed cooling system maintenance of the Mitsubishi 6UEC52LS main engine on MT. Princess Naomi, ensuring that the vessel remains seaworthy under all weather conditions and locations.

EXPERIMENTAL METHOD

The MT. Princess Naomi is a vessel owned by PT. Waruna Nusa Sentana, located at Jln. Boulevard Barat Raya, Kelapa Gading, North Jakarta. This ship is a type of tanker specifically designed for carrying product oil or refined petroleum products, featuring specialized specifications to ensure the safe and efficient transportation of these materials [15]. In its operations, the MT. Princess Naomi is chartered by Indonesia's state-owned oil and gas company, Pertamina. The ship's sailing routes are determined by Pertamina's charter agreements, as it transports refined petroleum products to various locations based on regional demand. This type of operation is known as tramp shipping, where the vessel's destinations are flexible and adjusted according to cargo requirements. The vessel's specifications are as follows:

Name Of Vessel	: MT. Princess Naomi
Call Sign	: YBEK 2
Owner	: Pt. Waruna Nusa Sentana
Builder	:Minaminippon Ship Building Co. Ltd. Japan Usuki
IMO Number	: 9126273
Mmsi Number	: 525020393
Immarsat Number (Tlx)	: 0722225193
Builder / Year	: 1995
Gross Tonnage	: 20024 Mt
Netto Tonnage	: 7644 Mt
Dwt	: 30.949 Mt
Loa	: 175.00 M
Lbp	: 166.00 M
Breadth	: 27.70 M

Depth	: 16.00 M
Air Draft	: 42.945 M
Main Engine	: Mitsubishi 6uec52ls
Auxiliary Engine	: 6135azcat / 138 Kw
Horse Power	: 10800 Hp


Figure 1 The MT. Princess Naomi

This research is a qualitative descriptive analysis, describing the optimization of the cooling system maintenance for the main engine, Mitsubishi 6UEC52LS, based on experiences during nearly a year of sailing aboard the MT. Princess Naomi. In this study, the researcher plays a crucial role. As stated by Sugiyono, qualitative research follows the post-positivist philosophy, which examines objects in their natural conditions. In this context, the researcher acts as the key instrument. Data collection techniques involve field research, combining observation, documentation, in-depth interviews, and literature review. Meanwhile, data analysis is conducted through triangulation (a combination of methods), not to seek absolute truth but to enhance the researcher’s understanding of the collected data and facts [16]. Data analysis is inductive/qualitative, and the research results emphasize the meaning of generalization rather than statistical representation. [17].

RESULT AND DISCUSSION

The Main Engine of MT. Princess Naomi uses an MITSUBISHI 6UEC52LS engine. It is a two-stroke engine with six cylinders and operates with a closed cooling system. The closed cooling system uses fresh water as the cooling medium, which circulates from the expansion tank. The water is pumped through the main engine at a temperature of 80°C, then cooled in a cooler to 70°C before recirculating to cool the main engine again. Seawater is only used to cool the fresh water through the cooler before being discharged overboard. Theoretically, the fresh water in this closed system should not decrease in volume. However, in practice, the cooling water volume decreases due to sedimentation, evaporation, and leaks.

The circulation process of the freshwater cooling system in the main propulsion engine includes the Expansion Tank, Fresh Water (FW) Cooling Pump, Cylinder Liner, Cylinder Head, and FW Cooler. Meanwhile, the seawater cooling system process in the freshwater cooler includes the Sea Chest, Filter/Strainer, FW Cooling Pump, Lubricating Oil (LO) Cooler, FW Cooler, and finally, the discharge overboard, as illustrated in Figure 2 below.

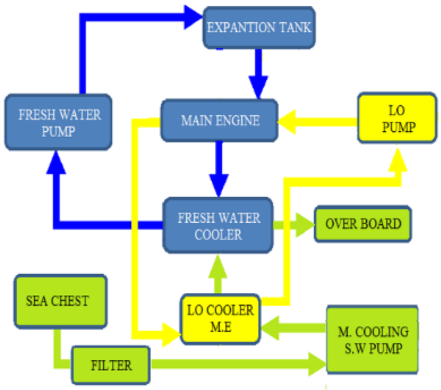

Figure 2 Cooling System Scheme of MT. PRINCESS NAOMI

Figure 2 Description:
- Blue = Fresh Water Flow
- Green = Seawater Flow
- Yellow = Lubricating Oil Flow

Fresh Water Cooling Circulation Process in the Main Engine

The components related to the freshwater cooling circulation system are:

Expansion Tank – A storage tank containing fresh water used to supply cooling needs in the engine room and other requirements. The expansion tank on MT. Princess Naomi has a capacity of 1000L. Regular maintenance is not performed, and only sediment removal is conducted. Complete maintenance is carried out during loading/discharging or when the expansion tank experiences issues such as failure to circulate water, leaks, low water levels, or discoloration. Maintenance includes checking water levels during each watch shift, refilling if necessary, draining excessive sediment, and cleaning the tank completely while docked. During cleaning, corrosion and rust are removed, and chemical treatment (Rocor NB Liquid) is added to slow down corrosion and sediment buildup.

Cylinder Liner – A cylinder bore where the piston moves up and down for compression. The freshwater cooling space is formed between the cylinder jacket and the cylinder liner.

Cylinder Head – Serves as a seal between the head and cylinder block, housing valves and manifolds, and facilitating cooling water and lubrication flow. Fresh cooling water enters through four openings in the cylinder jacket, flows into the exhaust valve, and exits through the cooling water outlet pipe.

Fresh Water Cooler – A component where fresh water is cooled using seawater as the cooling medium. Seawater flows through the freshwater cooler, cooling the freshwater passing between the plates. Maintenance includes wiping the exterior with a cloth to detect leaks, regularly cleaning the expansion tank's cooling water surface (once a month or when abnormalities occur), inspecting for visible damages, and checking the internal filters of the freshwater cooler.

The procedure for cleaning the plate cooler is as follows: First, cover the cooling water pump with a tarp and close the inlet and outlet cooling water pipe valves. Next, remove the inlet and outlet cooling water pipes connected to the cooler. Then, loosen and remove the bolts securing the cooler and detach the plates one by one. The accumulated scale is cleaned by scrubbing or using Chemical OSD (Oil Spill Dispersant), followed by rinsing with fresh water. After cleaning, inspect the condition of the cooler plates and their partitions. Once the inspection is complete, reassemble the cooler components as they were originally. After reassembly, clean the entire exterior of the cooler. Finally, start the cooling water pump and check for leaks. If the system operates smoothly and no leaks are detected, it can be put back into operation. The design of the freshwater late cooler can be seen in Figure 3 below.

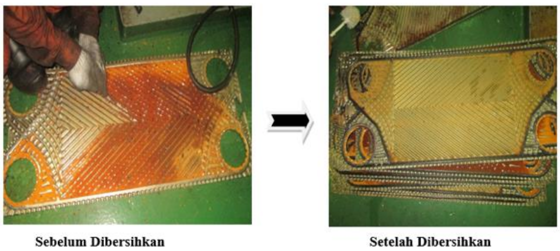

Figure 3 Fresh Water Plate Cooler of MT. PRINCESS NAOMI

Fresh Water Pump is a device used to transfer freshwater from one place to another. It operates using rotational energy derived from an engine or electric motor, utilizing a centrifugal mechanism where the liquid enters the impeller and flows within the casing. The MT. PRINCESS NAOMI is equipped with two freshwater cooling pumps that can be used alternately or as a backup in case of failure. Maintenance of centrifugal pumps is crucial to ensure optimal performance. If the pump fails to suction, the suction pressure gauge should be checked, as possible causes include an abnormal drive motor, air leakage in the pipeline, faulty valve seating, or a clogged packing seal. Other potential issues include blocked valves or lines, causing vacuum pump failure, and clogged strainers preventing proper suction. If suction occurs but water output is minimal, possible causes include blockages in the suction pipe or filter, partially or fully obstructed impeller blades, or excessive wear on the impeller ring. Preventive maintenance includes lubricating the pump bearings, regularly cleaning the suction strainer and impeller, replacing gland packing in case of leaks, and performing an overhaul if the pump circulation is inadequate.

Process of Seawater Cooling Circulation in the Seawater Cooler

Components Related to the Circulation of the Seawater Cooling System

1. Sea Chest

The Sea Chest is an opening in the ship's hull used to draw seawater into the vessel with the help of a pump. This seawater is used for engine cooling, ballast, deck washing, and other onboard needs. The seawater intake filter is a crucial part of the cooling system as it directly interacts with external seawater. Since various debris and objects in the sea can enter the main engine, a filter or strainer is installed. The strainer plate often encounters issues such as clogging due to debris or waste being sucked in, which reduces the effectiveness of the cooling system. Therefore, the Sea Chest requires regular maintenance to ensure the ship's cooling system operates efficiently, allowing smooth sailing without issues. Signs of a clogged or obstructed Sea Chest include the cooler becoming hotter than normal, a drop in seawater pressure as indicated by the manometer, a weak seawater flow overboard, and the activation of the low-pressure seawater alarm, accompanied by its warning light turning on.

To clean and maintain the Sea Chest, the inlet and outlet valves must first be closed. The Sea Chest cover or deck sheet should then be marked, and all securing bolts loosened before carefully removing the deck sheet to avoid damaging the gasket. The seawater inside the Sea Chest should be drained to check for any trapped debris, which must be removed. The filter plate or strainer should then be inspected. If it is still in good condition, it can be cleaned by spraying with water and scrubbing with a wire brush. If it is damaged, it must be replaced with a new one.

After cleaning or replacing the filter, it should be reinstalled, ensuring the gasket is correctly positioned before reassembling the deck sheet. All bolts should be reattached without fully tightening them. The seawater inlet valve should then be opened, and if water seeps from the gasket, two bolts should be tightened diagonally first, followed by evenly tightening all bolts in a crisscross pattern. The deck sheet should be cleaned, and grease should be applied to the securing bolts to prevent rust. The seawater outlet valve (overboard) should then be opened, and the pump should be started for a running test. If the system operates normally, the tools and surrounding area should be cleaned. Finally, all maintenance activities should be recorded in the engine room logbook.

2. *Sea Water Pump*

The Sea Water Pump (centrifugal) is a device used to transfer liquid from one place to another. It operates by utilizing rotational energy from an engine or electric motor to drive the pump. As the pump rotates, the liquid enters the impeller and flows within the casing, which directs the movement of the liquid.

The maintenance of the main cooling seawater pump includes regularly checking the seawater pressure through the pressure gauge and inspecting the gland packing for any leakage in the pump shaft. When the ship is underway and the pressure gauge indicates low pressure, the backup pump can be activated to assist in drawing seawater, ensuring the cooling of fresh water and lubricating oil remains effective.

3. *Lubricating Oil Cooler*

The Lubricating Oil Cooler is a component used to cool lubricating oil using seawater as the cooling medium. Seawater flows through designated passages within the zinc-plated plates, which are separated by barriers to prevent mixing between seawater and oil. This system ensures that the lubricating oil temperature is effectively reduced by seawater. For maintenance, it is essential to regularly check the temperature of both the Lubricating Oil Cooler and seawater at each watch shift. Additionally, every six months, the Lubricating Oil Cooler should be disassembled and cleaned by brushing the plates to remove any buildup, as illustrated in Figure 4.

Figure 4 Lubricating Oil Cooler of MT. PRINCESS NAOMI

4. *Over Board*

The Overboard is an opening in the ship’s hull used for discharging seawater from inside the vessel. Seawater that has been used to cool various engine components or wastewater from the ship is expelled through this outlet. On MT. Princess Naomi, some of the key components cooled by seawater include the Cylinder Jacket and Cylinder Liner. The Cylinder Jacket is the engine block that houses the Cylinder Liner and contains cooling water passages to regulate its temperature. Cooling water flows from an exhaust-side inlet and exits through four upper openings in the Cylinder Jacket, then enters the Cylinder Cover. The Cylinder Cover serves as the combustion chamber wall, sealing the cylinder bore within the engine block. The cooling passages in the Cylinder Cover direct water to the Exhaust Valve, which then flows into the cooling water outlet pipe.

Another essential cooled component is the Cylinder Liner, which is part of the Combustion Chamber. It is subjected to high pressure and significant friction due to the piston's continuous movement during compression. The cooling space is formed between the Cylinder Jacket and the Cylinder Liner, ensuring proper sealing. To maintain watertight integrity in the cooling water chamber surrounding the Cylinder, O-rings are fitted, with four cooling water inlet passages located at the lower section.

Effectiveness of Cooling System Maintenance Optimization

The cooling system on MT. Princess Naomi plays a crucial role in maintaining the optimal performance of the main propulsion engine. To ensure its effectiveness, a structured and thorough maintenance plan must be implemented. A detailed schedule is essential for monitoring and maintaining key engine components, allowing for timely and efficient upkeep.

Periodic maintenance involves routine checks conducted daily during engine room watch shifts. Engineers inspect cooling water pressure using manometers, ensuring that seawater pumps operate at 2.8 bar, while freshwater pumps maintain a pressure of 2.8 – 3.0 bar. Visual inspections are carried out to detect potential leaks, and the flow of cooling water is observed before and after engine startup. Maintenance tasks every 50 – 250 hours include cleaning seawater strainers, lubricating pump shafts, and ensuring that all cooling pumps function properly. More extensive inspections, conducted every 500 – 1000 hours, focus on cleaning the cooler's interior, checking the zinc anode, and inspecting the expansion tank for any sediment buildup that could affect water quality.

In contrast, unscheduled maintenance is performed in response to unexpected failures. Engineers monitor pump pressure and cooler temperatures to identify any abnormalities. In the event of a leak, the affected area is traced and repaired promptly. If a seawater pump failure occurs, an alternative general service pump is activated to maintain cooling operations while repairs are underway.

Through intensive maintenance, significant improvements were observed in the Mitsubishi 6UEC52LS main propulsion engine. The study focused on four essential cooling system components:

Expansion Tank – Responsible for maintaining the balance of cooling water volume.

Centrifugal Pump – Ensures the continuous circulation of cooling water throughout the system.

Fresh Water Cooler – This cools the freshwater circuit by transferring heat to seawater.

Sea Chest – Functions as the intake for seawater, supplying the cooling system with an uninterrupted flow.

A comparative analysis before and after maintenance optimization, based on manual book guidelines, is presented in Figure 5. This highlights the impact of routine and corrective actions in sustaining the efficiency and reliability of the cooling system.

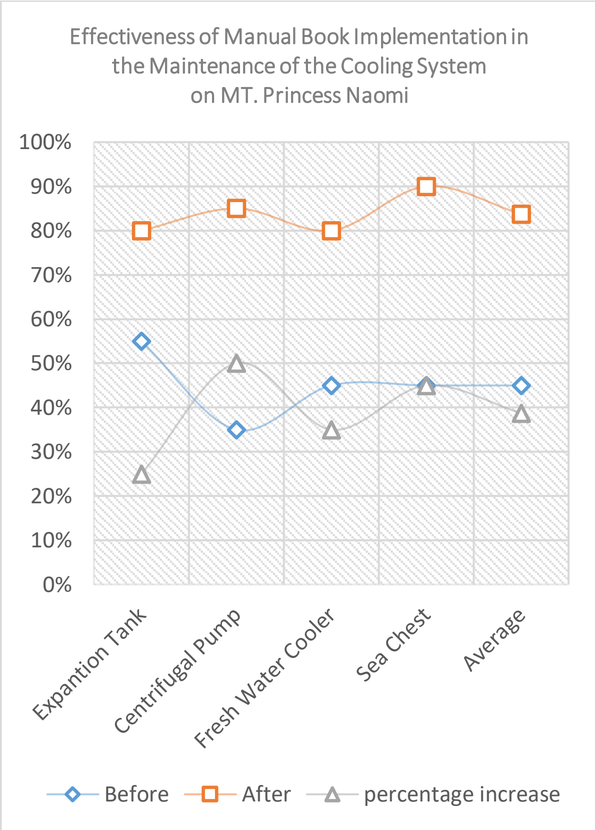

Figure 5 Graph of Cooling System Maintenance Optimization Effectiveness on MT. Princess Naomi

The graph above shows a significant increase in the effectiveness of manual book implementation for cooling system maintenance across all components. The expansion tank initially had an effectiveness of 55%, which increased by 25% after maintenance optimization, reaching 80%. Similarly, the centrifugal pump showed an improvement from 35% to 85%, with a 50% increase in effectiveness. Fresh water cooler experienced a 35% rise, from 45% to 80%, while the sea chest, which initially had an effectiveness rate of 45%, increased by 45%, reaching 90% after optimization.

Overall, before maintenance optimization, the average effectiveness of manual book implementation in the cooling system was approximately 45%. Following the structured implementation of manual book guidelines, the average effectiveness increased by 38.75%, resulting in an overall effectiveness of 83.75%. Based on these results, the closed cooling system maintenance for the main engine of MT. Princess Naomi, owned by PT. Waruna Nusa Sentana is proven to function optimally.

This finding aligns with Wibowo's research, which emphasizes that optimized cooling system maintenance ensures a vessel remains seaworthy in all weather and sea conditions[18]. The results of this study were compared with previous research examining maintenance methods and engine performance efficiency in similar contexts. For instance, Ardianzah (2014) found that a predictive maintenance approach using vibration analysis was more effective in reducing failure frequency compared to the corrective maintenance methods still commonly used.

A key distinction between this study and previous research lies in the evaluation parameters. This study specifically focuses on four critical cooling system components: the expansion tank, centrifugal fresh water cooler, and sea chest. Furthermore, variations in operational conditions and engine types significantly influence the findings, making them essential factors in assessing the effectiveness of the applied maintenance methods.

CONCLUSION

Based on research conducted in the engine room of the MT. Princess Naomi, owned by PT. Waruna Nusa Sentana, particularly regarding the maintenance of the main engine cooling system, several conclusions can be drawn. The cooling system maintenance for the MITSUBISHI 6UEC52LS main engine on the MT. Princess Naomi has been carried out effectively. Optimization has reached 83.75%, aligning with the manual book implementation for the diesel engine cooling system components. The main engine cooling system on the MT. Princess Naomi operates using a closed cooling system. The cooling system components that undergo maintenance include the expansion tank, centrifugal pump fresh water cooler, and sea chest.

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