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Failure Analysis and Optimization of Main Engine Cooling System Maintenance on a Fishing Vessel: A Case Study of KM. God Bless 08

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Abstract

The cooling system on a ship's main engine plays a crucial role in maintaining operational temperature stability but often encounters technical issues that can degrade engine performance and risk damage to critical components. This study identifies the factors causing failures in the cooling system of the main engine on KM. God Bless 08, particularly in the heat exchanger and pipeline components. Data were collected through field observations and direct measurements of freshwater and seawater temperatures at various operational points of the engine. The analysis revealed that the cooling system's performance significantly declined due to dirt deposits and corrosion in the capillary pipes, which hindered the efficiency of heat exchange between seawater and freshwater. The findings of this research provide insights for optimizing the cooling system through regular maintenance and component cleaning, essential for preventing overheating and improving the efficiency of the ship's main engine operations.

Keywords: Heat Exchanger, Fishing Vessel, Main Engine, Engine Maintenance, Cooling System

1. INTRODUCTION

So far, the common problem that often occurs in the main engine is the decline in cooling system performance, resulting in excessive heat, which causes the main engine to not function normally. In the main engine cooling system, there are many disturbances and damages that often occur because the cooling system operates continuously while the main engine is running. The disturbances experienced, especially in the closed cooling system, include issues such as clogged pipes due to dirt from the sea and freshwater pipe leaks due to long usage [1].

One of the most important factors of the main engine support system is the cooling system. If the cooling system is damaged, it will reduce the performance of the ship's main engine. As a result, this will cause losses for the shipowner both technically and economically. The purpose of the cooling system is to maintain the most efficient engine operating temperature at every speed under all conditions. The freshwater cooling system is one of the supports for the main propulsion system of a ship, where the function of the system is solely to cool the main engine so that it can operate normally [2].

One issue is the uncontrolled cooling system. The resulting impact is overheating, caused by damage to various supporting components of the cooling system. These include the connecting rod, cylinder liner, valve, fan belt, radiator, water pump, filter, piston, and hose [3]. The occurrence of overheating or excessive heat can endanger the main propulsion engine [4]. The increase in the main engine cooling water temperature affects engine performance [5]. Damage to the cooling system causes a decline in the main engine's performance and prevents it from operating optimally [6]. Major engine damage often occurs due to the failure of the cooling system and its components [7].

At PT. MITRA JAYA SAMUDERA, there are also frequent reports/complaints about the abnormal cooling temperature, which causes disruptions to the ship's journey. Therefore, the author conducted an observational study to examine the cooling system and the damage occurring in the main engine with the title Failure Analysis and Optimization of Main Engine Cooling System Maintenance on a Fishing Vessel: A Case Study of KM. God Bless 08.

2. METHODS

This study uses a quantitative descriptive approach to analyze the performance of the main engine cooling system based on the cooling water temperature. The data collected is quantitative, obtained through several methods: interviews, observations, documentation, and literature review.

- Interviews were conducted with the Chief Engineer (KKM) and two oilers to obtain information about the operational conditions and issues with the cooling system.
- Observations were made directly on KM. God Bless 08, monitoring the cooling water temperature to analyze the performance of the main engine cooling system.
- Documentation includes the collection of secondary data and the specifications of the main engine as references for the study.
- Literature review was sourced from articles indexed in Scopus, which served as the theoretical foundation for this research.

Measurements were taken on the main engine of KM. God Bless 08, which uses the Yanmar 6LAH-STE 3 engine model during operation. The tool used was a water temperature sensor with a temperature range of -10°C to 120°C, a default alarm value >95°C, and an accuracy of ±1°C (14°F) to measure the cooling water temperature of the main engine system.

The data analysis technique used in this study is quantitative descriptive analysis, which analyzes the causes of increased temperatures in the cooling system of the main engine based on the data obtained from observations and measurements.

3. RESULTS AND DISCUSSION

1. Analysis of Main Engine Cooling System Performance

The main engine cooling system works by absorbing the heat generated from the combustion of fuel inside the cylinder. The heat absorbed by the freshwater flows through the heat exchanger and is cooled by seawater, which flows through the heat exchanger pipes at a low temperature. The performance of the ship's main engine cooling system can be monitored by the temperature of the freshwater coolant exiting the engine. If the temperature of the freshwater coolant is high upon exit, the main engine needs to reduce its RPM. This will affect the ship's speed, reducing it.

The role of the heat exchanger in the cooling system is very important for engine performance because the heat exchanger is where the heat exchange occurs between the high-temperature freshwater, which absorbs heat from the engine, with a temperature range of 50°C-95°C. Once it enters the heat exchanger, the heat from the freshwater is absorbed by seawater with a temperature range of 29°C-33°C, depending on the seawater temperature in the area. The temperature of the freshwater will drop to 40°C-68°C, depending on the engine RPM. During the data collection on KM. God Bless 08, when the engine RPM was low, the heat exchange between the seawater and freshwater was more efficient. However, when the engine RPM exceeded 1,000 RPM, the heat exchange between the freshwater and seawater became less effective, causing the engine temperature to rise to 95°C. As a result, the engine's performance decreased due to the high engine temperature.

Several factors can cause the performance of the main engine cooling system to become abnormal, including:

1. Clogging of dirt in the seawater pipe channels, especially in the capillary pipes inside the heat exchanger.
2. Leakages in the seawater pipe channels.
3. Insufficient centrifugal pump pressure used to circulate the water.

The purpose of the main engine cooling system is to maintain the engine temperature within a stable and safe range:

1. Prevent engine damage due to excessively high temperatures.
2. Ensure the engine operates at maximum efficiency.
3. Reduce exhaust gas emissions.

2. Analysis of Main Engine Cooling System Damage

The freshwater temperature will increase if the cooling media (seawater) received is insufficient, causing the heat to rise due to excessive heat transfer, as heat flows from higher temperatures to lower temperatures.

The analysis conducted by the author during engine operation involved observing the cooling system components directly to check for any damage. The observations made on the main engine of KM. God Bless 08 can be seen in Table 1.

Table 1. Observation of Cooling System Components

No.	Component	Condition	Remarks
1.	Sea chest	Good	
2.	Pipes	Good	
3.	Seawater pump	Good	
4.	Seawater valve	Good	
5.	Heat exchanger	Good	Maintenance every 3 months
6.	Seawater pressure and temperature sensor	-	-
7.	Freshwater temperature and pressure sensor	Good	Seawater temperature sensor not installed
8.	Freshwater reserve tank	Good	
9.	Freshwater pump	Good	
10.	Freshwater valve	Good	

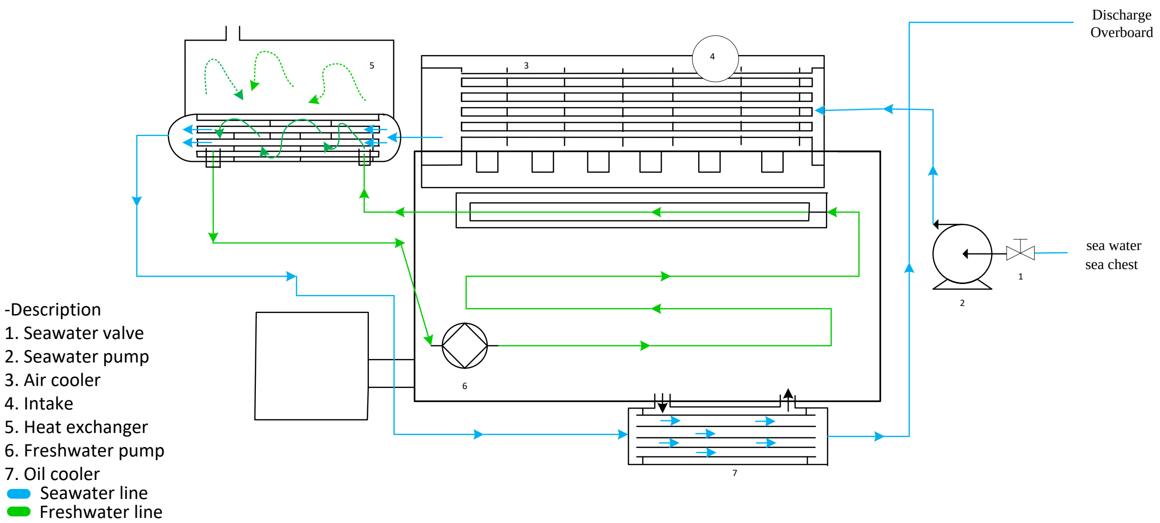

Figure 1. PFD of the Main Engine Cooling System

Before conducting the analysis, the author understood the operation of the main engine cooling system, starting from the seawater components and their circulation, as well as the freshwater line components. This understanding facilitated data collection and analysis of the damage occurring in the main engine cooling system.

While the author was on engine duty and analyzing the cooling system temperature by monitoring the freshwater temperature flowing to the heat exchanger for cooling, the engine temperature continued to rise and exceeded the recommended temperature of 70℃-80℃. This was caused by the seawater not absorbing heat from the freshwater due to the seawater contaminants clogging the capillary pipes in the heat exchanger. These contaminants obstructed the heat exchange process between the hot freshwater and the cold seawater, as the dirt and barnacles sticking to the pipes prevented the heat transfer from the water medium to the iron or copper pipes.

Figure 2. Freshwater Cooling System Temperature Measuring Instrument

Figure 3. Seawater Cooling System Temperature Measuring Instrument

When the author collected data from the incoming and outgoing seawater temperatures using a temperature measuring instrument, the sensor directly measured the water temperature by being installed inside the seawater inlet and outlet pipes. This allowed the author to analyze the temperature difference between the freshwater and seawater, enabling the prevention of damage by performing maintenance on the heat exchange area, i.e., the heat exchanger.

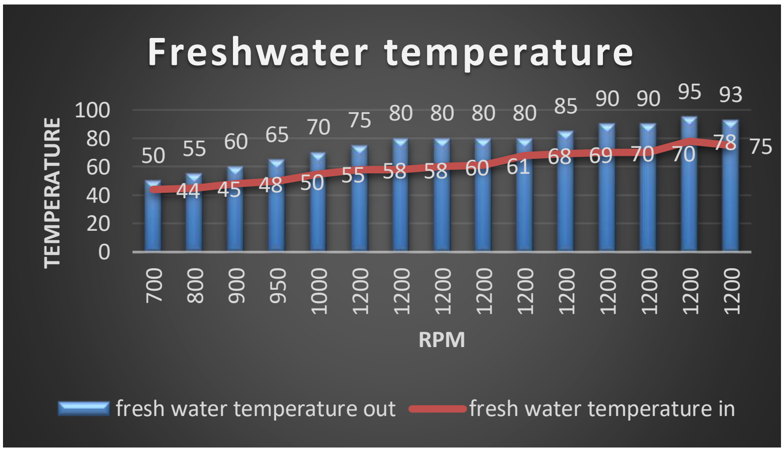

Figure 4. Difference in Freshwater Inlet and Outlet Temperature

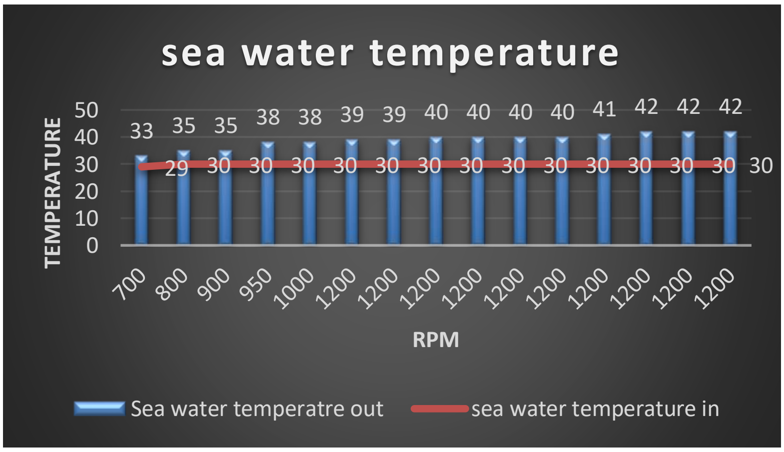

Figure 5. Difference in Seawater Inlet and Outlet Temperature

In Figures 4 and 5, the difference and temperature variation between the seawater and freshwater inlet and outlet temperatures can be observed. The author analyzes the cooling system's performance using measuring instruments, as shown in Figure 13. The very high temperature at 1200 RPM, reaching 95°C, while the normal temperature is 80°C, is caused by the ineffective heat transfer in the heat exchanger. The high temperature in the engine room, due to insufficient cold air entering the room, causes the room temperature to rise, leading to an increase in engine temperature.

Table 2. Analysis of Freshwater and Seawater Temperature Differences in the Main Engine

Temperature (°C) freshwater			Temperature (°C) Seawater		
In	Difference	*out*	*out*	Difference	In
44	6	50	29	4	33
45	10	55	30	5	35
48	12	60	30	5	35
50	15	65	30	8	38
55	15	70	30	8	38
58	17	75	30	9	39
58	22	80	30	9	39
60	20	80	30	10	40
61	19	80	30	10	40
68	12	80	30	10	40
69	16	85	30	10	40
70	20	90	30	11	41
70	20	90	30	12	42
78	12	95	30	12	42
75	18	93	30	12	42

When the author collected data while the engine was operating, analyzing the temperature of the main engine cooling system both the freshwater inlet and outlet and the seawater inlet and outlet using a temperature measuring instrument directly installed on the inlet and outlet piping of the cooling system, it was observed in Table 2 at 23:20 that the cooling water temperature reached 95℃. After being cooled in the heat exchanger, the temperature dropped to 78℃ before entering the engine to cool it, with only a 12℃ difference. Meanwhile, the seawater temperature, after cooling the freshwater inside the heat exchanger, was 42℃. The seawater temperature before cooling the engine was 30℃, with a temperature difference of only 12℃, indicating that the heat exchange inside the heat exchanger was ineffective. After disassembling the heat exchanger of the main engine, dirt was found on the outside of the pipes in the form of scale from freshwater evaporation, and inside the seawater pipes, there was dirt in the form of rust, sand, and barnacles. This debris obstructed the heat transfer from the hot freshwater to the cold seawater, causing the engine temperature to reach 95℃, exceeding the normal engine temperature of 80℃. This could lead to reduced engine performance, and the main engine components could expand due to the excessive heat.

3. Analysis of Main Engine Repair

The repair of the main engine cooling system can be done according to a routine schedule for each component. However, the analysis of cooling system repairs can also be conducted because, when a failure occurs in the main engine cooling system, it is essential to identify the cause before taking steps to repair it. In the case study of KM. God Bless 08, where the engine temperature rose to 95℃, exceeding the normal limit of 80℃, the author analyzed the cooling system repair to find the cause of the failure in one of the components.

The process of identifying the cause of the damage to the cooling system components involves comparing the temperatures of the freshwater and seawater. The heat from the freshwater should be transferred to the cold seawater. If the freshwater temperature out reaches 95℃ and the freshwater temperature in is 78℃, this means the water entering to cool the engine has only decreased by 12℃. This causes the engine temperature to continue rising because the seawater is not effectively absorbing the heat. This indicates an issue in the capillary pipe routes and heat exchanger, which are not functioning properly. Therefore, maintenance and repair on the heat exchanger should be carried out.

Based on the analysis of the temperature differences in the cooling system, maintenance should be performed on the heat exchanger and the capillary pipe routes by cleaning the debris that has accumulated on the surfaces, obstructing the heat transfer from the water to the copper pipes, which are conductors, whereas the debris acts as an insulator.


Figure 6. Heatexcahnger


Figure 7. Capillary pipes

During the dismantling of the main engine's heat exchanger, the dirt attached to the walls of the heat exchanger and in the capillary pipe lines causes ineffective heat exchange because it is obstructed by the dirt, which acts as an insulator. This dirt must be cleaned so that the surfaces of the pipes, which are conductors, can directly absorb heat from the water medium.


Figure 8. Cover of the heat exchanger pipes

The maintenance and repair steps for the heat exchanger, as performed on the main engine of KM. God Bless 08, are as follows:

1. Close the seawater valve to prevent seawater from entering, ensuring that no water flows out when the pipes are opened.
2. Open the nipple bolts to disconnect the pipe joint between the capillary pipe cover.
3. Open the heat exchanger covers, both for the inlet and outlet seawater lines.
4. Remove the capillary pipes inside the heat exchanger.
5. Clean the dirt attached to the walls of the heat exchanger using pressurized water and soap until it is clean.

6. Soak the capillary pipes in Portex for 1 hour and clean the pipe holes using stainless steel wire to remove any rust or barnacles.
7. Clean the dirt attached to the capillary pipe covers as well.
8. Once everything is confirmed clean, reassemble the components, starting with the installation of the capillary pipes and covers using new seals, reinstall the seawater pipe joints, and tighten the locking nipple.
9. Open the seawater valve and ensure there are no leaks in the seawater lines, especially at the pipe joints.

After performing maintenance on the heat exchanger, and operating the engine for 12 hours from when the ship departed from the fishing ground to the fishing base, the temperature of the engine started to normalize, reaching a maximum of 83℃, while the seawater inlet temperature was 57℃, showing a cooling difference of 25℃. Compared to before the maintenance, when the temperature only dropped by 12℃, as shown in Figure 9. The analysis of the improvements in the cooling water temperature is crucial to ensure the cooling system operates normally, preventing a decline in the performance of the main engine, which could hinder the ship's journey.

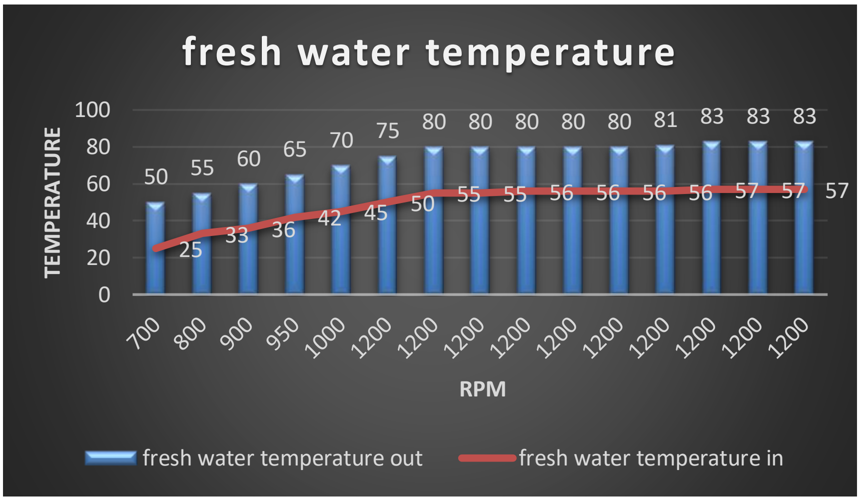

Figure 9. Difference in freshwater inlet and outlet temperature

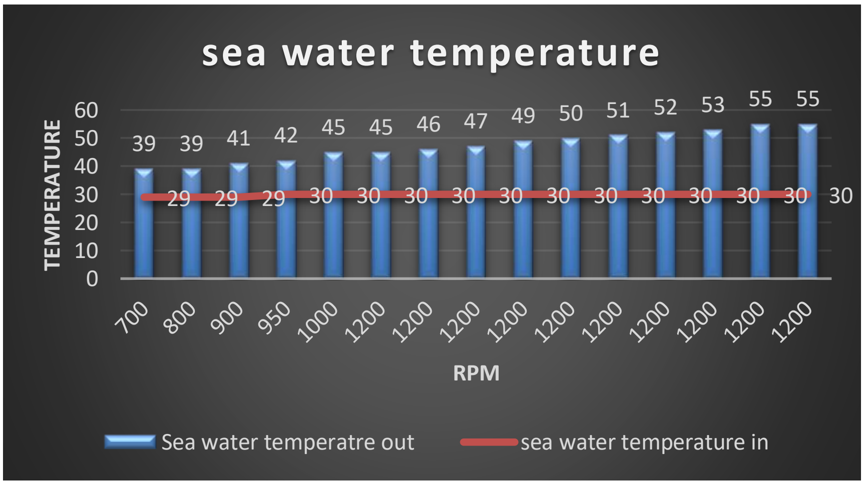

Figure 10. Difference in seawater inlet and outlet temperature

The heat absorbed by the seawater after the maintenance and repair of the heat exchanger is now effective compared to before the maintenance. This can be seen in Figure 11, which shows the difference in the freshwater outlet temperature.

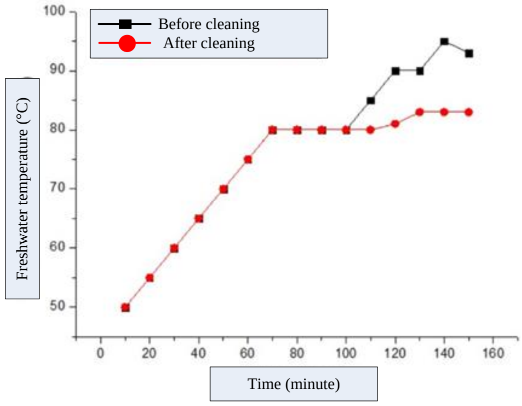

Figure 11. Temperature Difference

Table 3. Analysis of the temperature difference between freshwater and seawater in the main engine after maintenance

Temperature (°C) Freshwater			Temperature (°C) Seawater		
In	Difference	*Out*	*out*	Difference	In
25	25	50	39	10	29
33	22	55	39	10	29
36	24	60	41	12	29
42	23	65	42	12	30
45	25	70	45	15	30
50	25	75	45	15	30
55	25	80	46	16	30
55	25	80	47	17	30
56	25	80	49	19	30
56	25	80	50	20	30
56	25	80	51	21	30
56	25	81	52	22	30
57	25	83	53	25	30
57	25	83	55	25	30
57	25	83	55	25	30

Daily maintenance performed on the cooling system before operating the main engine:

1. Add freshwater to the heat exchanger tank using radiator coolant water, sometimes using regular freshwater.
2. Check the seawater pump's V-belt.

Table 4. Causes of cooling system damage and their repairs

No	Cause of Damage	Repair
1	Decreased pump pressure	Check the V-belt; if cracked or loose, replace it with a new one. Clean debris in the sea chest channel. Check the pump's impeller and seal.
2	Clogged heat exchanger	Clean the inside of the heat exchanger, especially the capillary tubes.
3	Insufficient coolant	Replace the seal on the pump and check the pipe routes for leaks. If any, repair the pipes by welding.

4. CONCLUSION

1. The main engine cooling system functions to transfer heat from the engine via a heat exchanger using freshwater and seawater. Performance is influenced by cleanliness, pump pressure, and component condition. By maintaining safe engine temperatures, this system prevents damage, maintains performance, and reduces emissions.

2. Main engine cooling system failure is often caused by blockages in the heat exchanger, which hinder heat transfer and raise the engine temperature above normal limits. Regular maintenance to clear blockages is effective in improving system efficiency and preventing overheating damage.
3. Cooling system repairs, including cleaning the heat exchanger and capillary tubes, effectively lower engine temperatures to normal levels. Routine maintenance ensures optimal performance and prevents operational disruptions on the ship.

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