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Case Analysis of Bowl Rotation Performance Deficiency in the FO Purifier of MV Manalagi Tara

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Abstract

The FO purifier auxiliary aircraft on board is a critical auxiliary machine in the fuel system. It separates fuel oil from air, mud, and dirt. When the researcher was conducting sea practice on the MV Manalagi Tara, the FO purifier auxiliary aircraft experienced damage, resulting in the release of oil into the sludge channel of the FO purifier, which caused a decrease in FO purifier performance. Then, the FO purifier was immediately turned off by Engineer Four before more oil came out, which caused a reduction in fuel oil.

Purpose - This study is to determine the factors causing the reduced performance of the bowl rotation on the FO purifier, the impact of the malfunction of the bowl rotation, and the failed performance of the bowl rotation on the FO purifier.

Methodology – The research method employed in this thesis is qualitative, utilizing the fishbone analysis technique.

Findings – The results from this study indicate that the factors causing the lack of bowl rotation performance on the FO purifier are dirty bowls, loose flat belts, damaged bowl shaft bearings, and worn bowl shafts. The impacts are caused by factors contributing to the lack of bowl rotation performance on the purifier. Efforts that can be made so that the rotation performance on the FO purifier can operate normally are cleaning the FO purifier bowl, adjusting the flat belt, replacing the bearing shaft, and the shaft bowl with new ones.

Originality – Understanding of mechanical condition and material degradation influence purifier performance in real ship operation.

INTRODUCTION

Ships are a more economical means of sea transportation compared to land and air transportation. With a larger load capacity, ships operate safely, quickly, and efficiently thanks to the support of strong ship engines and smooth operational processes (Bačkalov et al., 2016). Therefore, the smooth operation of ships has a significant impact on client satisfaction. The success of ship operations is highly dependent on the efficiency of the main propulsion engine, which is influenced by the type of fuel used. The quality

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of this fuel plays a vital role in the combustion process and directly affects the performance of ship engines. (Wahyuni, 2019).

Heavy Fuel Oil (HFO) is a type of fuel widely used on ships due to its relatively low cost compared to other marine fuels. However, HFO has high viscosity and contains contaminants such as sand, sludge, and water, which can make it unsuitable for direct use in engines. These impurities can lead to clogging of injector nozzles and reduced combustion efficiency. Therefore, fuel purification is essential to ensure clean fuel supply. This process is typically carried out using a centrifugal separator or purifier, which separates contaminants from the fuel before it enters the daily service tank (Suyono et al., 2021; Dwijayanti & Suryawan, 2022; Bagus, 2023).

If clean fuel is not available, it can significantly disrupt ship operations and even endanger voyage safety. This condition may occur if the purifier, which functions as the main equipment for producing clean fuel, does not operate properly. Several studies highlight that the performance of auxiliary purification systems directly influences engine reliability and operational continuity at sea. Maintaining optimal viscosity and cleanliness of fuel oil is essential, as improper viscosity affects atomization and combustion efficiency in the main engine. Therefore, a purifier or self-jector system is used to ensure fuel quality before entering the service tank (Prakoso et al., 2020; Wahyudi & Setiawan, 2021; Bagus, 2023).

Based on the background that has been explained, the incident experienced by researchers on the MV ship. Manalagi Tara occurred during a trip from Kalimantan to Sulawesi on April 25, 2023. The sound was quite loud on the FO purifier, which prevented the device from operating optimally.

This study aims to deepen knowledge and experience in purifier maintenance and solve problems related to purifier auxiliary aircraft on ships. This study specifically seeks to identify factors that cause a decrease in the performance of the bowl rotation on the FO purifier, analyze the impacts that arise due to the reduction in the performance of the bowl rotation on the FO purifier and formulate efforts that can be made to restore the performance of the bowl rotation on the FO purifier to normal conditions.

1. Definition of FO Purifier

A Fuel Oil (FO) purifier is an auxiliary machine used to clean and purify fuel oil from contaminants such as water, sludge, and solid particles. This process is crucial for maintaining the quality of fuel used in marine engines and power plants, ensuring efficient operation and minimizing the risk of mechanical damage. The purifier operates based on centrifugal separation principles, which involve rotating the bowl at high speed to remove impurities from the oil (MAN Energy Solutions, 2020; Raju & Pratama, 2021; Bagus, 2023).

2. Working principle of FO Purifier

FO purifiers operate on the principle of centrifugal separation, where the fuel oil is rotated at high speed to separate heavier particles such as water and sediment from the lighter fuel oil. The separation process occurs as the centrifugal force pushes denser materials outward while the purified oil moves inward toward the clean oil outlet. The efficiency of this process depends on factors such as rotational speed, oil viscosity, and temperature (Alfa Laval, 2019; Suryawan & Rahman, 2022).

a. Oil Inlet: Dirty fuel oil enters the purifier through the inlet. Here, the oil is usually separated from the storage tank.
b. Centrifugation: After entering, the oil flows into a rotor that rotates at high speed. The resulting centrifugal force separates the components based on their density. Heavier particles, such as water and mud, are trapped outside the rotor, while lighter oil is on the inside.
c. Contaminant Collection: These separated contaminants will collect in certain system parts, usually under the rotor. Water and mud will be removed periodically.
d. Clean Oil Release: Oil that has been processed and cleaned.
e. Temperature and Pressure Regulation: This process is often regulated by heating to reduce the oil's viscosity and increase the efficiency of separation. Pressure can also be controlled to ensure optimal performance.

f. Automatic Control: Many modern FO purifiers are equipped with automatic systems that monitor the condition and quality of the oil, ensuring that the purification process runs effectively.

From this explanation, the primary function of the purifier is to separate oil from other particles. The purified fuel oil produced by the FO purifier ensures clean combustion and stable engine operation. Clean oil helps prevent clogging of injector nozzles, reduces carbon deposits, and supports optimal main engine performance during continuous operation (IMO, 2020; Prakoso et al., 2020; Wahyudi & Setiawan, 2021). It is known that oil or fuel is supplied when the bunker is still dirty, so it requires a separation and cleaning (purification) process (Bagus, 2023). If this problem is not resolved immediately, it will negatively impact the lubricating oil separation process, resulting in suboptimal performance.

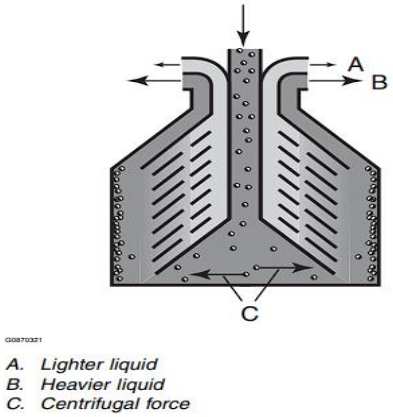

Figure 1. Bowl hydraulic system
Source: Alfa Laval (2019)

3. FO Purifier Components

Figure 2. Part of the Main components of the FO purifier on the ship.

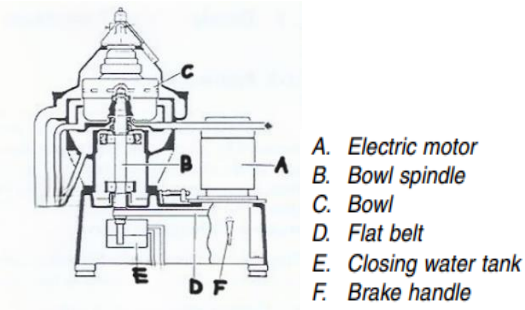

Figure 2. Main components of FO purifier
Source: Alfa Laval (2019)

a. Electric motor
The electric motor rotates the bowl spindle using a drive belt. It provides the power needed to rotate the rotor at high speed, enabling the centrifugation process to separate contaminants from the fuel oil.

b. Bowl spindle
The bowl spindle/shaft bowl functions as a shaft that connects the rotor (Bowl) to the drive motor. It enables the rotor to rotate at high speed, facilitating the centrifugation process. The bowl spindle is designed to provide rotational stability during the purification process.

c. Bowl
The bowl section has several components, including the hood, body, and disc stack. The Bowl that rotates at high speed produces centrifugal force. Solid particles with higher specific gravity will be thrown and stick to the Bowl.

d. Flat belt
A flat belt is a connecting belt tool to connect the electric motor and the Bowl spindle. This allows the Bowl to rotate, making the separation and purification process more effective.

e. Closing water tank
A closing water tank stores closing water in the fuel purification system, especially in the Fuel Oil Purifier. Here are some points about its function: Storage, cooling, control, pressure, water circulation, Monitoring, and Maintenance.

f. Brake handle
The brake is a part that is useful for reducing rotation or stopping the Bowl when the purifier is operating and will be maintained or serviced.

g. Bowl discs
Bowl discs are components in the FO purifier purification system. This disc can enhance the filtration process or separation of particles, and it is often made of specific materials that facilitate absorption or filtration.

h. Gasket
The gasket is a part of the FO purifier used to prevent leakage between two surfaces that are in contact, usually found in the engine component system, including the FO purifier. The gasket serves to reduce vibration and compensate for unevenness.

4. Fuel

According to Nasution (2022), fuel can be converted into energy if mixed with air in the proper proportions. Examples are gasoline, natural gas, coal, wood, heavy oil, diesel, and other organic materials. Fuel is a liquid that can be converted into energy through combustion or other chemical reactions. Fuel is used for multiple purposes, including driving vehicles, generating electricity, and heating rooms. Each fuel type has different characteristics, uses, and other environmental impacts. Fuel is essential in ship operations to ensure the efficiency and sustainability of the voyage.

RESEARCH METHOD

This study uses a qualitative research method. Qualitative research seeks to understand reality through an inductive thinking process (Sitanggang, 2019). Researchers are directly involved in the situation and background of the phenomenon in this study, focusing on the actual operational issues of the FO purifier on board.

The qualitative approach was chosen because this research aims to explore and describe the causal factors and operational impacts of decreased bowl rotation performance through direct observation and interviews rather than numerical measurement. This approach enables a deeper understanding of maintenance procedures, crew decision-making, and technical conditions that impact the purifier's performance — aspects that cannot be fully captured using quantitative methods (Creswell & Poth, 2018; Sutopo, 2020).

Researchers obtain information directly from primary sources or investigation locations. While practicing on the MV Manalagi Tara, researchers obtain primary and secondary data. The problem raised in this study concerns the FO purifier, and primary data is obtained. Researchers obtain primary data by conducting observations and interviews with resource persons, specifically Machinist 4, regarding the maintenance of the FO purifier on the MV Manalagi Tara.

Secondary research data does not come from the subject or the first source used for research (Nasution, 2023). Secondary data supports primary data to strengthen or provide additional evidence. Secondary data sources are beneficial because they enable faster information collection without requiring the direct collection of primary data. Secondary data can also result from data collection by other parties for specific purposes. Researchers usually use secondary data sources such as operational records and interviews with the machinists on board.

This study uses various data collection methods to ensure the accuracy of the information. These methods include direct observation of the FO purifier on the MV Manalagi Tara during sea practice, focusing on problems related to the FO purifier's machinery, especially the analysis of bearing damage that resulted in the performance of the FO purifier's auxiliary aircraft not being optimal. In addition to observation, interviews were conducted with Machinist 4, responsible for the FO purifier, to obtain information that may not be included in the manual. Discussions with fellow cadets were also undertaken to compare problems on other ships. Finally, documentation in the form of notes, photos of engine parts during repairs and maintenance, and all related materials to the FO purifier were also used as supporting evidence in this study. The study was carried out during the researcher's onboard training period from October 2022 to December 2023. The data were collected through direct observation, interviews with ship engineers, and review of the ship's maintenance documentation.

This study uses qualitative methods to analyze verbal and oral data from the researcher's marine practice experience aboard the ship. The data were analyzed using a Fishbone diagram. The Fishbone, or Ishikawa, diagram is a structured qualitative analysis tool used to systematically identify and classify the root causes of a problem. Its use in this study is justified because the research focuses on understanding the causal factors behind the decreased bowl rotation performance in the FO purifier — a complex technical issue influenced by multiple interacting variables such as machine condition, maintenance practices, and operational environment.

In qualitative case studies, the Fishbone approach provides a visual and analytical framework for organizing non-numerical data from observations and interviews, making it suitable for identifying cause–and–effect relationships in engineering maintenance problems. The data were analyzed using a Fishbone diagram with a 2M approach, explicitly focusing on Machine (equipment) and Material (materials). The 2M approach was selected because the performance deficiency in the FO purifier was primarily caused by mechanical conditions and component quality, rather than human, method, or environmental factors. During observation, the malfunction was directly linked to physical wear on the bowl shaft, bearing damage, and dirt accumulation — all of which fall within the domains of machine and material analysis. Therefore, focusing on the 2M technique allowed for a more accurate identification of the root technical causes related to equipment performance (Ishikawa, 1986; Mulyono & Suryawan, 2021; Prakoso et al., 2020).

RESULTS AND DISCUSSIONS

The problem analysis in this study was conducted qualitatively using the Fishbone method to identify the factors contributing to the decrease in bowl rotation performance of the FO purifier aboard the MV Manalagi Tara. A specific case occurred on April 25, 2023, during the vessel's voyage from Banjarmasin (South Kalimantan) to Makassar (South Sulawesi). While operating the FO purifier during the second engine watch (2000–2400), the researcher observed an abnormal vibration and rumbling noise coming from the purifier unit. The Fourth Engineer decided to stop the purifier to prevent further oil leakage from the sludge discharge line. Subsequent inspection revealed that the bowl's rotation had slowed significantly, and oil sludge was found accumulated inside the bowl casing.

To support these observations, semi-structured interviews were conducted with the Fourth Engineer, Oiler, and Engine Cadet responsible for the purifier. The Fourth Engineer explained: "The purifier had been running continuously for weeks without cleaning because we were maintaining daily operations. The vibration started two days ago, but we kept it running until it became too unstable." Then, the Oiler confirmed that the flat belt was loose and covered with oil residue. This triangulation of data confirmed that delayed maintenance and mechanical wear were the leading causes of reduced bowl rotation performance.

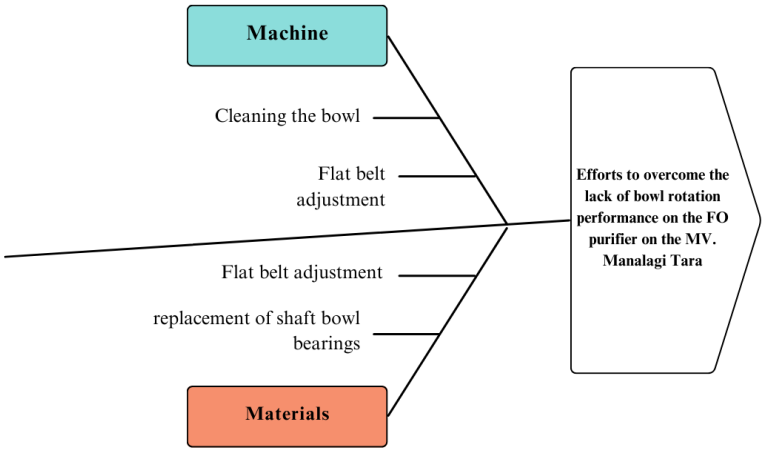

Figure 3. Fishbone Diagram
Source: Research data, 2023

The following is a discussion resulting from the analysis using the Fishbone method.

1. Factors causing poor bowl rotation performance on the FO purifier at MV. Manalagi Tara
   a. Machine factors

      Machine factors are influenced by the age and working hours of the machine. The longer the machine operates, the greater the possibility of damage. Based on the researcher's experience, machine factors cause abnormal bowl rotation on the FO purifier. The researcher identified the following causes of machine factors based on observations, interviews, and literature studies.

      1) Dirty bowl: The bowl is the main component in the FO purifier; it functions as a container where the fuel purification process utilizes centrifugal force. The centrifugal force in this tool plays a crucial role in separating fuel from water, dirt, and other particles based on their density differences. Fuel oil with a lighter density than other particles will collect in the middle and spread up towards the centripetal pump and out towards the clean fuel oil channel. If the purifier is not cleaned regularly, dirt (such as lime, mud, or crust) can accumulate in the bowl. Without regular maintenance, the cleanliness of the bowl will worsen.

Figure 4. Dirty bowl
Source: Research data, 2023

A dirty or clogged bowl can interfere with the performance of the FO purifier. Dirt and water that should be removed through the de-sludging process can accumulate in the bowl if this process does not run perfectly. As a result, the separation of fuel from water

and dirt is not optimal. Accumulated dirt can block the flow of clean fuel, causing it to mix with the dirty fuel. This causes the FO purifier to work inefficiently, shortens its life, and reduces the performance of the bowl rotation.

2) Dirty flat belt: The flat belt is an essential FO purifier transmission system that connects the bowl shaft to the electric motor shaft. The flat belt plays a role in maintaining effective bowl rotation to separate dirt from fuel. However, the flat belt can become loose due to continuous use. Improper installation, lack of maintenance, and excessive friction can cause wear and damage to the flat belt. A loose or weak flat belt is more easily damaged by pressure and rotation in the fuel purification process, which can cause a lack of bowl rotation performance in the FO purifier.

b. Material Factors

Material factors are one of the causes of poor bowl rotation performance on the FO purifier on the MV Manalagi Tara. This is influenced by the availability of spare parts, where the quality of reconditioned spare parts differs from that of new ones. The use of reconditioned and replication spare parts that do not meet standards can result in component damage. Some causes of problems related to material factors are:

1) Damage to the Bearing Shaft Bowl: The bearing shaft bowl supports the shaft bowl. Damage to this component, such as wobble and widening of the inner diameter, is caused by the inability to withstand the bowl load, which is too heavy due to dirt buildup. This damage affects the rotation of the bowl and causes the fuel oil to mix back with dirt.
2) Wear on the Shaft Bowl: Wear on the shaft bowl is also a factor causing poor bowl rotation performance. Wear occurs on the part of the shaft bowl where the bearing shaft bowl is installed. This is caused by the inner diameter of the bearing shaft bowl, which widens, causing slippage between the two. This wear causes unstable rotation and affects the process of separating oil from water and dirt.

2. The Impact of the lack of bowl rotation performance on the FO purifier at MV. Manalagi Tara

One of the supporting factors for producing clean fuel is the fuel system. The fuel system plays a vital role in engines that use a compression process to operate according to need. Therefore, the quality of the fuel oil must always be maintained. A good FO purifier can clean fuel oil from water and dirt. Researchers observed the conditions that occurred due to the lack of bowl rotation performance on the FO purifier. Researchers found various impacts of the lack of bowl rotation performance on the FO purifier as follows:

a. Impact of machine factors (Machine)

1) The bowl becomes heavy: A good FO purifier produces good and clean fuel oil quality. Based on observations, researchers found that the lack of bowl rotation performance on the FO purifier had an impact on the decline in the quality of fuel entering the service tank. This was caused by the dirty bowl condition. Dirt deposits that accumulate in the bowl cause its weight to increase. Separating oil from water and dirt in a filthy bowl cannot run perfectly.
2) The flat belt becomes slippery: An efficient FO purifier can operate according to needs, as a fuel purifier that produces sound and clean fuel oil quality. Based on the results of observations, researchers found that the Impact of the lack of bowl rotation performance on the FO purifier is a decrease in rotation caused by unstable bowl rotation due to the flat belt. The flat belt becomes slippery when it does not move at the required speed, which can reduce the quality of the processed oil, and the purification results will not be optimal, causing the oil to contain still dirt or particles that are not properly filtered. A flat belt becomes slippery can cause an overload on the electric motor or drive system, because the flat belt cannot provide enough rotation to move the bowl components efficiently, the motor or drive can work harder than it should, causing the electric motor or drive components to wear out faster or even be damaged due to excessive load. A flat

belt that becomes slippery can cause excessive vibration and produce noise due to the instability of the slipping flat belt movement, which can accelerate wear on components and increase the risk of further damage to the system.

b. Impact of material factors (Material)

The material factor is the third Impact of the causal factors caused by the lack of bowl rotation performance on the FO purifier. From the results of observations, interviews, and literature studies conducted by researchers on the material factor, it can be seen below:

1) Rumbling sound on the FO purifier: The FO purifier, when the bearing shaft bowl is damaged, will hear a rumbling sound when the FO purifier is operating. Damage to the bearing shaft bowl also causes the bowl to vibrate because the bearing shaft bowl is damaged or already shaking. Vibrations in the rotation of the bowl cause the separation process to be imperfect, where the fuel that should have been separated from the dirt becomes mixed again due to the vibration.
2) Unstable bowl rotation: Shaft bowl wear is one of the factors that causes a decrease in bowl rotation performance on the FO purifier. This wear occurs because the inside of the bearing shaft bowl is damaged, causing slippage between the shaft bowl and the shaft. When the inside of the bearing is damaged, the rotation load from the shaft bowl cannot be distributed evenly, causing friction wear on the shaft. The wear on the shaft bowl causes the rotation to become unstable because the rotational load of the bowl is not correctly distributed to the bearing. This condition impacts the process of separating oil from water and dirt, becoming imperfect, because the centrifugal force produced does not reach what is needed due to unstable rotation in the FO purifier.

3. Efforts to overcome the lack of bowl rotation performance in the FO purifier.

Based on the observation, literature study, and interview methods conducted by researchers while carrying out sea practice at MV Manalagi Tara. Several are mad that the FO purifier's performance can operate normally again and not be repeated in the future. In the following, the researcher found several efforts to deal with the problem, which have been grouped according to the factors that cause it, among others:

a. Efforts to deal with influences arising from machine factors (Machine)

Here are some efforts to improve and prevent the problem from recurring in the future. The following are efforts so that the performance of the FO purifier can operate normally again from the machine factor:

1) Cleaning the bowl: Efforts to deal with the lack of bowl rotation performance in FO purifiers, one of the machine factors that needs to be considered is bowl cleaning. Following periodic PMS (Plan Maintenance System), Bowl maintenance must be carried out regularly. In FO purifiers, cleaning is done every 4000 hours of operation. During the cleaning process, all bowl components, including the bowl disc, must be cleaned of dirt deposits that stick. After washing, the bowl is reassembled, and this activity is recorded in the PMS as a reference for the following maintenance schedule.
2) Flat belt adjustment: To deal with the lack of bowl rotation performance in FO purifiers, the machine factor that needs to be considered is the flat belt adjustment. Check regularly to ensure that the flat belt is at the proper tension. Routinely check and clean the flat belt and pulley from dirt or oil that can reduce traction. If the flat belt is too loose, it will cause it to slip, transfer power from the electric motor less efficiently, so adjust the tension.

b. Efforts to handle influences arising from Material factors

In terms of material factors, the efforts made by researchers to deal with the lack of bowl rotation performance in the FO purifier so that it can operate normally again are as follows:

1) Replace the bowl shaft bearing: To overcome the damage to the bearing shaft bowl, replace the bearing with a new one; the bearing replacement must be as listed in the

manual. Ensure the bearing shaft bowl is installed correctly and can rotate smoothly. After installation is complete, record the time of operation. This record is vital for monitoring bearing life and determining the following maintenance schedule.

2) Perform shaft bowl replacement: After identifying the causes and effects of the lack of bowl rotation performance in the FO purifier, based on this description, an effort needs to be made to overcome the wear problem on the shaft bowl. The solution is to replace the shaft bowl with spare parts that match the specifications of the FO purifier manual. After replacement, it must be ensured that the shaft bowl does not experience slippage or installation errors that can cause the shaft to wear out or tilt. Then record it in the PMS as a reference for the next maintenance.

CONCLUSIONS

The purifier malfunctioned due to mechanical and material issues, including bowl contamination, a loose flat belt, a worn shaft, and damaged bearings. These conditions led to unstable rotation, excessive vibration, and a decrease in fuel purification efficiency. Fishbone analysis identified the root causes and clarified that the main problems were linked to improper maintenance intervals and component wear. Corrective actions, such as cleaning the bowl, adjusting belt tension, and replacing worn parts, successfully restored regular purifier operation. Thus, the integration of qualitative analysis provided a comprehensive understanding of the influence of mechanical condition and material degradation on purifier performance in real ship operations.

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