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Causes of Reduced Seawater Pump Pressure on Board KM Amukti Palapa

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ABSTRACT
This study aims to identify the factors causing reduced seawater pump pressure on board KM Amukti Palapa, examine the impacts of pressure reduction on pump performance, and propose appropriate maintenance measures to ensure normal operation. The research employed a descriptive qualitative approach using data collected through direct observation, interviews with engine officers and technical personnel, documentation review, and relevant literature studies. The findings indicate that reduced seawater pump pressure is primarily caused by discharge valve leakage, blockages in the discharge line, pump overloading, impeller damage, and human error. These conditions may result in unstable pump loading, cavitation, inefficient energy consumption, damage to seals, bearings, piping systems, and increased maintenance costs. The study further highlights the importance of implementing a comprehensive preventive maintenance program, including routine inspections, component replacement, cleaning procedures, performance monitoring, crew training, and proper documentation. Effective maintenance management and continuous monitoring can significantly improve pump reliability, reduce operational disruptions, and extend the service life of seawater pump systems on board vessels.

Keywords: Seawater Pump, Pump Pressure, Centrifugal Pump, Preventive Maintenance, Ship Cooling System.

I. Introduction

During shipboard operations, auxiliary machinery plays a fundamental role in maintaining the reliability, safety, and efficiency of marine engineering systems. Among these auxiliary systems, pumps are considered one of the most essential components because they ensure the continuous circulation and transfer of liquids required for cooling, lubrication, ballast, firefighting, bilge operations, and domestic water supply. Without a properly functioning pumping system, the operational continuity of the main engine and supporting equipment may be severely disrupted, potentially leading to equipment failure, operational delays, or even emergency situations. Consequently, maintaining optimal pump performance has become a critical aspect of marine engineering maintenance and ship operation (McGeorge, 2015).

A pump can generally be defined as a mechanical device that converts mechanical energy supplied by a prime mover into hydraulic energy by increasing the pressure and velocity of a liquid, thereby enabling the fluid to flow from one location to another. Pumps are classified into two major categories: positive displacement pumps and dynamic pumps. Among dynamic pumps, centrifugal pumps are the most widely used in marine applications due to their relatively simple construction, high operational efficiency, continuous flow characteristics, ease of maintenance, and ability to handle large volumes of seawater under varying operational conditions (Karassik et al., 2008).

In modern merchant vessels, seawater centrifugal pumps are indispensable components of the central cooling system. They continuously circulate seawater through heat exchangers to remove excess heat generated by the main propulsion engine, auxiliary engines, lubricating oil coolers, air compressors, freshwater cooling systems, and other heat-producing equipment. This cooling process ensures that machinery operates within the manufacturer's recommended temperature range, thereby preventing overheating and minimizing the risk of mechanical damage. According to the International Maritime Organization (IMO, 2021), maintaining the reliability of auxiliary machinery, including cooling systems, is an integral part of ship safety management because failures in these systems may compromise both machinery integrity and navigational safety.

The operating principle of a centrifugal pump is based on the conversion of rotational kinetic energy into hydraulic energy. Mechanical energy from the electric motor or engine is transmitted to the impeller, causing it to rotate at high speed. As the impeller rotates, the fluid located between the impeller blades experiences centrifugal force and is propelled radially outward from the center toward the impeller periphery. This movement increases the fluid velocity significantly. Subsequently, the high-velocity fluid enters the volute casing or diffuser, where the cross-sectional area gradually expands, allowing the kinetic energy (velocity head) to be converted into pressure energy (pressure head). Simultaneously, the departure of liquid from the impeller eye creates a region of relatively low pressure, which enables additional liquid to be drawn continuously into the pump through the suction line. This continuous cycle produces an uninterrupted flow of seawater necessary for shipboard cooling operations (Stepanoff, 1957; Karassik et al., 2008).

Despite their relatively robust design, centrifugal pumps are vulnerable to various operational problems that may significantly reduce their performance. One of the most common issues encountered onboard ships is a reduction in discharge pressure. A decline in pump pressure can adversely affect the overall cooling capacity of the seawater system, leading to insufficient heat removal from marine machinery. If left unresolved, this condition may result in abnormal increases in engine operating temperature, reduced machinery efficiency, accelerated component wear, increased maintenance costs, and in severe cases, complete machinery shutdown (McGeorge, 2015).

Several technical factors have been identified in previous engineering studies as contributing to reduced centrifugal pump pressure. These include excessive wear of the impeller due to erosion or corrosion caused by seawater, blockage of the suction strainer by marine debris or biological fouling, leakage through worn mechanical seals or stuffing boxes, cavitation caused by inadequate suction conditions, air ingress into the suction pipeline, deterioration of bearings resulting in shaft misalignment, and excessive internal clearance between rotating and stationary components (Bloch & Geitner, 2012). Additionally, long-term exposure to seawater accelerates corrosion and mineral deposition inside pump casings and pipelines, gradually reducing hydraulic efficiency and increasing flow resistance. These conditions emphasize the importance of preventive maintenance programs and routine inspections to ensure sustained pump performance.

Another significant phenomenon affecting centrifugal pump performance is cavitation. Cavitation occurs when the local pressure within the pump falls below the vapor pressure of the liquid, causing vapor bubbles to form and subsequently collapse violently as they move into higher-pressure regions. The repeated collapse of these vapor bubbles generates localized shock waves that damage impeller surfaces, reduce hydraulic efficiency, increase vibration and noise, and ultimately shorten the service life of the pump. According to Çengel and Cimbala (2018), cavitation is one of the primary causes of efficiency loss in centrifugal pumps and should be prevented through proper suction system design, adequate Net Positive Suction Head (NPSH), and routine operational monitoring.

The effectiveness of shipboard maintenance practices also plays a decisive role in ensuring the reliability of seawater pumps. Modern marine maintenance systems emphasize preventive and condition-based maintenance rather than corrective maintenance. Preventive maintenance includes periodic inspection of impeller conditions, bearing lubrication, alignment verification, seal replacement, vibration monitoring, pressure testing, and cleaning of seawater strainers. Such maintenance activities reduce the likelihood of unexpected failures and contribute to longer equipment service life. The International Safety Management (ISM) Code further requires shipping companies to establish planned maintenance systems that ensure all machinery essential to the safe operation of the ship remains in satisfactory working condition (IMO, 2021).

The practical importance of maintaining adequate seawater pump pressure became evident during the operation of KM Amukti Palapa, where a noticeable reduction in seawater pump discharge pressure was observed. The decrease in pressure affected the cooling water circulation system, thereby reducing cooling efficiency for several auxiliary and main engine components. Preliminary observations indicated that the pressure reduction may have been associated with mechanical wear, obstruction within the seawater suction system, or inadequate maintenance procedures. Such conditions have the potential to compromise operational safety if corrective measures are not implemented promptly.

Considering the strategic importance of centrifugal seawater pumps in supporting marine engineering operations and ensuring continuous vessel performance, identifying the underlying causes of pressure reduction is essential for improving maintenance effectiveness and operational reliability. Understanding the technical factors responsible for pressure loss will enable marine engineers to develop appropriate corrective actions, optimize maintenance schedules, and minimize the risk of equipment failure during voyage operations.

Based on the foregoing discussion, the author has selected this problem as the focus of an Applied Scientific Paper (ASP) entitled "Causes of Reduced Seawater Pump Pressure on Board KM Amukti Palapa." This study aims to identify the technical and operational factors contributing to the reduction of seawater pump pressure, analyze their impact on the ship's cooling system performance, and propose practical recommendations that may improve the reliability, efficiency, and safe operation of seawater centrifugal pumps onboard the vessel. It is expected that the findings of this study will provide useful references not only for marine engineers serving aboard KM Amukti Palapa but also for the broader maritime industry in enhancing maintenance management practices for auxiliary machinery.

II. Literature Review and Hypothesis Development

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2.1. Definition of a Pump

A pump is one of the most essential auxiliary machines used in marine engineering and industrial systems for transferring liquids from one location to another by increasing the energy of the fluid. Pumps are indispensable in various shipboard operations, including cooling systems, ballast operations, bilge systems, firefighting systems, fuel transfer, and freshwater supply. Their primary function is to convert mechanical energy supplied by a prime mover into hydraulic energy, allowing fluids to flow through piping systems while overcoming differences in elevation, pressure, and friction losses (Karassik et al., 2008).

According to Poerwanto and Herry Gianto (1998), a pump is a mechanical device used to transfer liquid from one place to another by creating a pressure difference between the suction and discharge sides. During operation, the pump converts mechanical energy from a driving source into kinetic and pressure energy, enabling the fluid to overcome resistance within the piping system. Similarly, McGeorge (2015) explains that a pump divides its operating system into two principal sections: the suction side and the discharge side. The suction side is limited by the maximum vacuum that can be produced, whereas the discharge side can theoretically generate much higher pressures depending on the pump design and operating conditions. This pressure difference forms the fundamental principle that enables continuous liquid movement through the system. On board ships, seawater pumps are specifically designed to circulate seawater continuously through cooling systems. These pumps play a crucial role in maintaining the operational temperature of the main engine, auxiliary engines, lubricating oil coolers, central cooling systems, and other heat-exchanging equipment. The pump operates by increasing the fluid pressure and velocity sufficiently to overcome static head, pressure differences, and friction losses within pipelines and heat exchangers. Consequently, the reliability of seawater pumps directly influences the efficiency, safety, and operational continuity of marine propulsion and auxiliary machinery (McGeorge, 2015).

Based on their operating principles, pumps are generally classified into two major categories: positive displacement pumps and dynamic pumps. Positive displacement pumps transfer a fixed volume of liquid during each operating cycle, making them suitable for high-pressure and low-flow applications. In contrast, dynamic pumps continuously increase the velocity of the liquid before converting that velocity into pressure energy. Among dynamic pumps, the centrifugal pump is the most widely employed in marine and industrial applications due to its ability to deliver a continuous flow at relatively high capacities with a simple mechanical structure (Karassik et al., 2008).

According to Saputra (2010), a centrifugal pump is a dynamic pump that transfers fluid through the rotational motion of an impeller. As the impeller rotates, centrifugal force accelerates the liquid radially outward from the impeller eye toward its outer circumference, thereby increasing the fluid velocity. The high-velocity liquid then enters the volute casing or diffuser, where the kinetic energy is converted into pressure energy before the fluid exits the pump. This operating principle enables centrifugal pumps to provide continuous flow with relatively stable pressure characteristics under normal operating conditions.

The popularity of centrifugal pumps is attributed to several engineering advantages. These pumps have relatively simple construction, fewer moving parts, lower maintenance requirements, compact dimensions, smooth operation with minimal vibration, and high efficiency when operated near their design point (Stepanoff, 1957). Furthermore, centrifugal pumps can handle large volumes of seawater with relatively low operational costs, making them particularly suitable for marine cooling

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systems and other shipboard auxiliary services. However, their performance is highly dependent on proper operating conditions. Factors such as cavitation, impeller wear, air leakage, corrosion, clogging of suction strainers, and inadequate maintenance can significantly reduce pump capacity and discharge pressure, ultimately affecting the overall efficiency of the ship's cooling system (Bloch & Geitner, 2012).

Therefore, understanding the working principles, classifications, and operational characteristics of pumps—particularly centrifugal pumps—is essential for marine engineers. Such knowledge enables effective maintenance planning, early fault diagnosis, and the implementation of corrective measures that ensure the reliability and safe operation of shipboard machinery throughout the vessel's service life.

2.2. Definition of Pressure

Pressure is the force exerted per unit area on a surface. It occurs when a force acts perpendicular to an object and is influenced by factors such as force, area, temperature, and volume. The International System (SI) unit of pressure is the pascal (Pa), where 1 Pa = 1 N/m^2. Pressure can be classified into three main types:

a. Pressure in Solids

Pressure in solids is generated when a force is applied to a surface. The magnitude of pressure depends on the applied force and the contact area. Greater force produces higher pressure, while a larger contact area reduces pressure.

b. Liquid Pressure (Hydrostatic Pressure)

Hydrostatic pressure is the pressure exerted by a liquid at rest. It is caused by the weight of the liquid and increases with depth. The magnitude of hydrostatic pressure depends on the liquid density, gravitational acceleration, and depth.

c. Gas Pressure

Gas pressure results from the force exerted by gas molecules on the walls of a container. In the Earth's atmosphere, this pressure is known as atmospheric pressure, which is approximately 76 cmHg at sea level. In a closed system, the relationship between gas pressure and volume is described by Boyle’s Law, which states that pressure is inversely proportional to volume when temperature remains constant.

2.3. Types of Pumps

Pumps are generally driven by motors or engines and are designed according to the type of fluid, flow rate, transportation distance, and required pressure. Based on their operating principles, pumps can be classified into the following types:

a. Positive Displacement Pumps

Positive displacement pumps move a fixed volume of fluid during each operating cycle. The fluid is trapped and forced from the suction side to the discharge side with minimal backflow. These pumps are capable of producing high pressure at relatively low flow rates.

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- Reciprocating Pumps: Reciprocating pumps generate pressure through the back-and-forth motion of a piston or plunger driven by a crankshaft. They are equipped with suction and discharge valves that regulate fluid flow automatically. These pumps can produce very high pressures but generally operate at low speeds and have large, heavy constructions.
- Rotary Pumps: Rotary pumps operate through the rotational movement of internal components such as gears, screws, or vanes. Fluid is trapped between the rotating elements and the pump casing before being forced to the discharge side. They can operate at high rotational speeds and are widely used due to their compact design and efficient performance.

b. Piston Pumps

Piston pumps use the reciprocating motion of a piston within a cylinder to draw in and discharge fluid. They are commonly used in applications requiring high pressure and low flow capacity.

c. Dynamic Pumps

Dynamic pumps increase fluid pressure by converting mechanical energy into kinetic energy and then into pressure energy. Their working chamber volume remains constant during operation. The main types of dynamic pumps are axial pumps and centrifugal pumps.

- Axial Pumps: Axial pumps move fluid parallel to the pump shaft through the action of a rotating impeller. They are suitable for applications requiring high flow rates and low pressure, such as irrigation and drainage systems.
- Centrifugal Pumps: Centrifugal pumps are among the most widely used pumps in industrial and marine applications. They operate by converting the kinetic energy generated by a rotating impeller into pressure energy. Fluid enters the center of the impeller and is discharged radially at high velocity, creating a continuous flow. Due to their simple design, reliability, and ease of operation, centrifugal pumps are commonly used for seawater and other fluid-transfer systems. The pressure or total head produced by a centrifugal pump increases proportionally with the square of the impeller's rotational speed.

2.4. Main Components of a Centrifugal Pump

A centrifugal pump consists of several essential components that work together to ensure efficient fluid transfer. The main parts are described as follows:

a. Stuffing Box: The stuffing box prevents leakage where the pump shaft passes through the casing.
b. Packing: Packing is installed inside the stuffing box to minimize fluid leakage along the shaft.
c. Shaft: The shaft transmits rotational power from the driver to the impeller and supports other rotating components.
d. Shaft Sleeve: The shaft sleeve protects the shaft from wear, corrosion, and erosion, particularly in the stuffing box area.
e. Vanes: Vanes are the blades of the impeller that direct and accelerate the fluid flow.
f. Casing: The casing encloses the pump components, guides fluid flow, and converts velocity energy into pressure energy.

g. Eye of the Impeller: The eye of the impeller is the inlet section where fluid enters the impeller from the suction side.
h. Impeller: The impeller is the primary rotating component that converts mechanical energy into kinetic energy, enabling continuous fluid movement.
i. Wearing Ring: The wearing ring reduces internal leakage between the impeller and casing, helping maintain pump efficiency.
j. Bearing: Bearings support the shaft, reduce friction, and ensure smooth rotation under radial and axial loads.
k. Discharge Nozzle: The discharge nozzle directs the pumped fluid out of the pump and delivers it at a higher pressure than at the inlet.

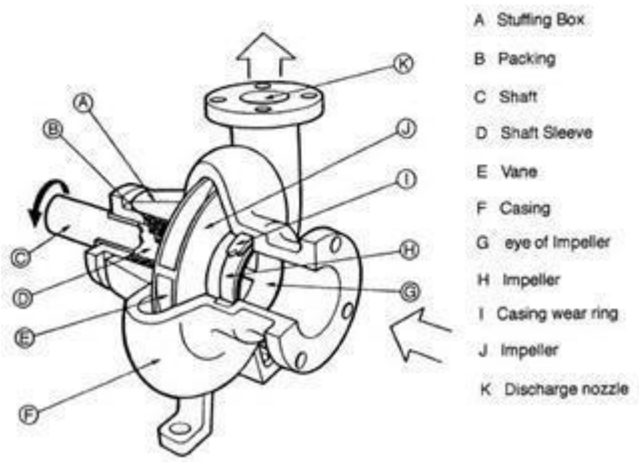

Figure 1. Main Components of a Centrifugal Pump.

2.5. Working Principle of a Centrifugal Pump

A centrifugal pump is a type of non-positive displacement pump that operates by converting mechanical energy into fluid energy. Its working principle can be summarized as follows:

a. Energy Conversion by the Impeller: Mechanical energy from the driving unit is converted into fluid kinetic energy through the centrifugal force generated by the rotating impeller.
b. Velocity-to-Pressure Conversion: The high-velocity fluid flows through the volute casing or diffuser, where its velocity decreases and its kinetic energy is converted into pressure energy.
c. Fluid Discharge: The pressurized fluid is discharged through the outlet (discharge side) of the pump, providing the required flow and pressure for the system.

In summary, a centrifugal pump works by converting mechanical energy into kinetic energy, which is then transformed into pressure energy to move fluid efficiently through the system.

III. Research Method

3.1. Research Method

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This study employed a descriptive analysis method to examine the data presented in this Applied Scientific Paper. Descriptive analysis is used to describe and explain events occurring on board related to the operation and maintenance of the fresh water generator. Based on direct observations and available data, the study aims to provide an appropriate solution to the identified problems.

3.1.1. Data Collection Methods

Data were collected using the following methods:

a. Field Research

Field research was conducted through direct observation of the research object on board the vessel. Data and information were obtained through:

- Observation – Direct observation was carried out during onboard practice activities to examine the maintenance procedures of the fresh water generator.
- Interviews – Interviews were conducted with engine officers on board, as well as lecturers and supervisors from the Makassar AMI Maritime Polytechnic, to obtain relevant information and technical insights.

b. Library Research

Library research involved reviewing books, journals, manuals, and other relevant literature to establish the theoretical foundation for the study.

c. Documentation Research

Documentation research was conducted by collecting and reviewing records, reports, manuals, photographs, and other related documents to support and validate the data obtained from observations and interviews.

3.1.2. Types and Sources of Data

a. Types of Data

This study uses qualitative data, consisting of descriptive information obtained through observations, interviews, and documentation related to seawater pump performance.

b. Sources of Data

The data used in this study consisted of both primary and secondary data. Primary data were obtained directly from the vessel through interviews with engine officers, the Chief Engineer, and technical personnel regarding the operation and maintenance of seawater pumps on board. Meanwhile, secondary data were collected from relevant literature, operational manuals, journals, and scientific articles related to the research topic. The combination of these data sources provided comprehensive information to support the analysis and discussion of the study.

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3.2. Research Period

The research was conducted during the author's practical training program, which began following the official deployment of cadets from Politeknik Maritim AMI Makassar by the Director, Amrin, on August 7, 2025. The practical training was carried out at PT. Satria Samudera Lines from August 12, 2025, to November 12, 2025, for a total duration of three months. Operational activities were conducted from Monday to Friday in accordance with the company's regular working schedule. However, employees were also required to be present outside normal working hours, including weekends and public holidays, whenever vessel berthing, loading, or unloading operations were taking place.

3.3. Research Location

This research was conducted at PT. Satria Samudera Lines, an Indonesian private shipping company engaged in ship agency and maritime transportation services. Established in 2022 under the leadership of its President Director, Hj. Nursiah Satria, the company provides operational and agency services for national shipping vessels operating in Indonesian waters. In addition to ship agency services, PT. Satria Samudera Lines is involved in cargo transportation and logistics operations. The company manages and operates several vessels, including MV Golden Ace, MV Golden Rejeki, MV Golden Permai, KM Amukti Palapa, SPOB Putra Kalimas 7, and KM Berguna. The study was specifically conducted on board KM Amukti Palapa, an Indonesian-flagged cargo-passenger vessel operating in domestic shipping routes. The vessel has a gross tonnage (GT) of 745 tons and a deadweight capacity of 500 tons, with an overall length of 51 meters, a beam of 9 meters, and a draft of 3.19 meters. KM Amukti Palapa is powered by two Yanmar main engines rated at 620 HP each and two Perkins auxiliary engines rated at 124 HP each, enabling a maximum service speed of approximately 12 knots. The vessel is designed to accommodate up to 300 passengers while simultaneously carrying cargo, making it an important component of regional maritime transportation. The object of this research was the seawater cooling pump installed on board KM Amukti Palapa. The pump plays a critical role in supporting the vessel's cooling system by supplying seawater for heat exchange processes. The pump investigated in this study was manufactured by Shin Shin Machinery, model ESC-120C, with a capacity of 8 m^3/h, an operating speed of 1,200 rpm, an output power of 5.5 kW, a frequency of 50 Hz, and a voltage rating of 220 V. The seawater cooling pump was selected as the research object due to the occurrence of reduced discharge pressure, which affected the efficiency and reliability of the vessel's cooling system during operation.

IV. Result and Discussion

4.1. Factors Causing a Decrease in Seawater Pump Pressure

a. Leakage in the Discharge Valve

Leakage in the discharge valve is one of the factors that can cause a decrease in seawater pump pressure on board a vessel. This problem may occur due to maintenance or repair activities on the pump and piping system, allowing seawater to enter or escape from the system. Leakage can also result from

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technical issues such as mechanical damage to the valve, improper pressure conditions, or failure of the automatic control system. In some cases, seawater pumps that operate infrequently may experience valve deterioration, leading to leakage and reverse flow that can damage internal pump components. Additionally, operational mistakes, such as failing to reopen the discharge valve after maintenance activities, may contribute to pressure loss. Therefore, thorough inspections of the pump, valve, and piping system are necessary to identify the root cause and prevent further operational problems.

b. Blockage in the Discharge Line

Blockages within the seawater cooling system are another common cause of reduced pump pressure. Seawater naturally contains contaminants such as sand, mud, seaweed, shells, and other debris that can accumulate in pipes if strainers and filters are not functioning properly or are inadequately maintained. Furthermore, marine organisms such as barnacles, mussels, and algae may attach to the inner surfaces of pipes, creating biofouling that restricts water flow. Corrosion products from metal components exposed to seawater can also detach and obstruct the cooling passages. In polluted waters, oil residues, chemicals, and waste materials may adhere to the piping system and accelerate blockage formation. Salt deposits resulting from seawater evaporation can further reduce flow capacity over time. Consequently, regular inspection, cleaning, and preventive maintenance of the cooling system are essential to ensure uninterrupted seawater circulation and maintain optimal pump performance.

c. Overloading

Overloading occurs when the seawater pump is required to operate beyond its normal capacity, resulting in excessive stress on the motor and mechanical components. This condition may be caused by blockages in the suction or discharge lines, forcing the pump to work harder to maintain water flow. Cavitation, which occurs when suction pressure becomes too low, can also reduce pump efficiency and increase motor load. The presence of air in the suction system may lead to loss of priming, causing the motor to consume more power while attempting to maintain operation. In addition, worn impellers, damaged bearings, electrical faults, shaft misalignment, and operating the pump above its design specifications can significantly contribute to overloading. To minimize these risks, regular maintenance and proper monitoring of both mechanical and electrical components are required to ensure the pump operates within its intended performance range.

d. Impeller Damage

Impeller damage is a critical factor affecting the performance and pressure output of seawater pumps. One of the primary causes is cavitation, where vapor bubbles form and collapse near the impeller surface, resulting in erosion and material loss. Corrosion caused by continuous exposure to seawater can also weaken the impeller, particularly when corrosion-resistant materials or protective measures are insufficient. Additionally, abrasive particles such as sand and sediment carried by seawater may erode the impeller surface and accelerate wear. Foreign objects, including shells, seaweed, and debris, can become trapped within the impeller, causing imbalance and physical damage. Excessive vibration, improper operating conditions, high temperatures, and inadequate maintenance may further contribute to impeller deterioration. Implementing routine inspections, selecting suitable materials, and

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operating the pump according to design specifications are essential measures for extending impeller service life and maintaining system reliability.

e. Human Error

Human error is one of the most significant contributors to seawater pump failures and pressure reduction in marine operations. Operational mistakes, such as failing to follow established procedures, can adversely affect pump performance and lead to equipment damage. Inadequate maintenance practices, delayed inspections, and improper calibration of system settings may cause the pump to operate inefficiently or beyond its designed capacity. Errors in equipment selection, installation, and monitoring can further increase the likelihood of mechanical and operational failures. Moreover, neglecting maintenance procedures and insufficient supervision may allow minor issues to develop into serious system malfunctions. Factors such as fatigue, workload pressure, and lack of training can also impair decision-making and increase the risk of operational errors. Therefore, continuous training, strict adherence to standard operating procedures, and effective supervision are crucial for reducing human error and ensuring the safe and reliable operation of seawater pump systems.

4.2. Impacts of Reduced Seawater Pump Pressure

A decline in seawater pump pressure can have significant adverse effects on the performance and reliability of the pump system. Excessive pressure reduction may cause operational inefficiencies, increase mechanical stress on pump components, and ultimately result in equipment failure. The following are the major impacts associated with reduced seawater pump pressure.

a. Unstable Pump Loading

A pressure drop beyond the pump's design limits can increase the workload imposed on the pump. When the pump is forced to operate outside its optimal operating range, critical components such as the motor and impeller are subjected to excessive mechanical stress. This condition can lead to overheating of the motor, accelerated wear of the impeller, and a reduction in overall pump efficiency. Prolonged operation under unstable loading conditions may eventually result in component failure and reduced system reliability.

b. Cavitation

Reduced pump pressure can trigger cavitation, a phenomenon that occurs when the pressure at the suction side of the pump falls below the vapor pressure of the fluid. Under these conditions, vapor bubbles form and subsequently collapse as they move into areas of higher pressure within the pump. The implosion of these bubbles generates intense localized forces that can erode the impeller and other internal components. In addition to causing physical damage, cavitation reduces pump efficiency, increases vibration levels, and may lead to severe mechanical failures if left unaddressed.

c. Inefficient Energy Consumption

Uncontrolled pressure reduction can cause the pump to operate inefficiently, resulting in unstable energy consumption. To maintain the required water flow rate, the electric motor may need to draw additional power, thereby increasing energy usage beyond the planned operating level. This

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excessive power demand can place additional strain on the electrical system and may eventually lead to motor overloading, reduced equipment lifespan, and higher operating costs.

d. Damage to Seals and Gaskets

Excessively low pressure can adversely affect sensitive components such as seals and gaskets, which are designed to prevent leakage within the pump system. When operating conditions deviate from the intended pressure range, these components may deteriorate more rapidly and lose their sealing effectiveness. As a result, leakage can occur, leading to reduced system performance, increased maintenance requirements, and a higher risk of damage to adjacent components.

e. Damage to Piping and Supporting Components

Low pump pressure can also negatively affect supporting system components, including pipes, valves, and flanges. Inadequate pressure conditions may create operational imbalances within the piping system, potentially causing leaks, joint failures, or structural weaknesses. Over time, these issues can compromise the integrity of the entire cooling system and require costly repairs or component replacements.

f. Bearing Wear

Operating under excessively low pressure can subject the pump bearings to loading conditions that differ from those for which they were originally designed. As a result, bearing wear may accelerate, reducing their ability to support smooth impeller rotation. Damaged bearings can lead to shaft misalignment, increased vibration, and reduced pump efficiency. If not corrected promptly, bearing failure may cause severe and permanent damage to the pump assembly.

g. Increased Maintenance Costs

An increase in maintenance costs is one of the most significant consequences of reduced seawater pump pressure. Pressure-related problems can damage various system components, reduce operational efficiency, and increase the frequency of maintenance activities. Components such as impellers, bearings, seals, valves, and piping systems may require more frequent inspections, repairs, or replacements. Furthermore, unexpected equipment failures can result in operational downtime, additional labor costs, and higher expenditures for spare parts. Consequently, maintaining proper pump pressure is essential for minimizing maintenance costs and ensuring the reliable operation of the vessel's seawater cooling system.

4.3. Maintenance of Seawater Pumps to Ensure Normal Operation

A well-planned maintenance program for seawater pumps is essential to ensure efficient operation and prevent failures that may lead to downtime, costly repairs, or disruptions to vessel operations. Effective maintenance not only extends the service life of pump components but also enhances the reliability and performance of the entire cooling system. The following maintenance measures are recommended to keep seawater pumps operating under normal conditions.

a. Establishing a Routine Maintenance Schedule

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A structured maintenance schedule should be implemented to ensure that the seawater pump remains in optimal condition. Daily inspections should include checking fluid levels and the overall condition of the pump to identify any leaks or signs of damage. Pump pressure and flow rates should also be monitored regularly to verify that the system is operating within the specified parameters. Weekly inspections should focus on the physical condition of the pump and related systems, including pipes, valves, and connections, while also checking for unusual vibrations or abnormal noises that may indicate developing issues. Monthly maintenance should involve thorough cleaning of the pump and associated components, as well as inspection and replacement of filters or strainers when necessary. Quarterly inspections should include comprehensive examinations of both mechanical and electrical components, with lubrication applied to moving parts as required. In addition, annual inspections should be conducted by qualified technicians to evaluate the overall condition of the pump, replace worn components, and perform calibration procedures when necessary.

b. Inspection and Replacement of Critical Components

Critical pump components should be inspected regularly to ensure their reliability and performance. The impeller should be examined periodically for signs of wear, corrosion, erosion, or physical damage, and replaced if significant deterioration is detected. Seals and gaskets should also be inspected for leakage and wear, as their failure can compromise system integrity and efficiency. Furthermore, bearings and shafts should be checked to ensure proper alignment and operation. Regular lubrication should be carried out according to manufacturer recommendations, and worn bearings should be replaced promptly to prevent further mechanical damage.

c. Cleaning and Preventive Maintenance

Routine cleaning plays a vital role in maintaining seawater pump efficiency. The pump should be cleaned regularly to remove dirt, marine growth, debris, and other materials that may interfere with its operation. Appropriate cleaning agents should be used, and all components should be thoroughly dried before reassembly. In addition, the cooling system connected to the pump should be cleaned periodically to prevent blockages, corrosion, and efficiency losses. Preventive maintenance activities help ensure uninterrupted seawater circulation and reduce the risk of unexpected failures.

d. Monitoring and Performance Testing

Continuous monitoring and regular performance testing are necessary to ensure the pump operates within its design specifications. Pressure and flow sensors should be installed to provide real-time monitoring of system performance and to detect abnormalities at an early stage. The pump should also undergo periodic operational testing under various working conditions to verify its functionality and reliability. Such testing helps identify potential issues before they develop into serious failures and contributes to the overall efficiency of the seawater cooling system.

e. Documentation and Reporting

Accurate documentation is an essential part of an effective maintenance program. Detailed records should be maintained for all maintenance activities, including inspection dates, maintenance procedures performed, and component replacements. These records provide valuable information for tracking equipment condition and planning future maintenance activities. Additionally, any faults or

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abnormalities discovered during inspections should be documented in maintenance reports, along with recommendations for repair or replacement. Proper documentation supports effective decision-making and contributes to the long-term reliability of the pump system.

f. Training and Awareness

Proper training is crucial to ensuring that crew members and technicians can perform maintenance tasks effectively and safely. Personnel should receive adequate instruction on seawater pump operating principles, inspection procedures, cleaning methods, troubleshooting techniques, and repair practices. In addition, crew members should be familiar with emergency procedures in the event of sudden pump failure. Increased awareness and adherence to established maintenance procedures can significantly reduce operational errors and improve overall equipment reliability.

g. Spare Parts Planning and Procurement

Effective spare parts management is necessary to minimize downtime and ensure timely repairs. Critical spare parts should always be available onboard or easily obtainable from nearby ports. Maintaining an inventory of essential components, such as bearings, seals, gaskets, impellers, and filters, can prevent delays during maintenance and repair activities. Furthermore, stored spare parts should be inspected periodically to ensure they remain in good condition and are ready for use when needed.

h. Evaluation and Continuous Improvement

The maintenance plan should be reviewed periodically to assess its effectiveness and identify areas for improvement. Evaluations should be based on operational experience, maintenance records, equipment performance data, and feedback from technicians and crew members. Findings from these evaluations can be used to refine maintenance procedures, optimize inspection intervals, and improve overall system reliability. Continuous improvement initiatives, including the adoption of advanced monitoring technologies and updated maintenance practices, can further enhance the performance and longevity of seawater pump systems.

V. Conclusion

Based on the discussion and analysis presented in this study, it can be concluded that the decrease in seawater pump pressure is primarily caused by inadequate preventive maintenance, including insufficient inspection of the pump, valves, strainers, pipelines, impellers, piping systems, and electric motors. In addition, errors in maintenance procedures and improper operational practices contribute significantly to the deterioration of pump performance. Therefore, ship crews should receive adequate training in the operation and maintenance of seawater pumps to minimize operational errors and improve the reliability of the system. A reduction in seawater pump pressure can result in various types of damage to critical pump components, including the impeller, seals, bearings, motor, and associated piping systems. These failures may reduce operational efficiency, increase maintenance requirements, and shorten the service life of the equipment. To prevent such problems, pump pressure should be continuously monitored to ensure operation within the specified design limits. Furthermore, chemical cleaning using appropriate cleaning agents should be performed when necessary to remove scale, deposits, and contaminants that cannot be eliminated through manual cleaning methods. Such

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maintenance activities should always be conducted in accordance with the manufacturer's recommendations to ensure safety and effectiveness.

To maintain optimal seawater pump performance and prevent unexpected failures, a comprehensive maintenance program should be implemented. This program should include routine inspections, cleaning procedures, performance monitoring, and the timely replacement of critical components. In addition, a structured preventive maintenance schedule covering all major pump components should be established to improve system efficiency and reliability. Proper maintenance planning can significantly reduce the risk of equipment failure and minimize operational downtime. Finally, effective maintenance management should be supported by comprehensive documentation and adequate spare parts availability. Detailed records of all maintenance and repair activities should be maintained to monitor equipment condition, evaluate maintenance effectiveness, and ensure that routine maintenance is carried out on schedule. Maintaining sufficient inventories of critical spare parts will also help facilitate timely repairs and reduce delays in restoring equipment to normal operation. Through proper maintenance practices, continuous monitoring, crew training, and effective documentation, the operational reliability and service life of seawater pump systems can be significantly improved.

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