The Effect of Refrigerant Pressure on The Accommodation Cooling System on The MV. Meratus Medan 1 Ship

Lely Widyaningrum[1*], Agus Prawoto[2], Dyah Ratnaningsih[3], Antonius Edy Kristiyono[4], Intan Sianturi[5]

[1,2,3,4,5] Surabaya Maritime Polytechnic Applied Undergraduate Study Program,
Ship Machinery Engineering Technology, Indonesia.
*Corresponding Author:
Email: lelywidya53@gmail.com

Abstract

Main engines in marine diesel vessels require optimal cooling systems to maintain thermal efficiency amid fluctuating operational loads. This study analyzes the effect of coolant temperature on thermal efficiency of the main engine aboard MV Pritha. Employing a quantitative descriptive-analytic approach, data were collected from operational parameters (RPM, inlet/outlet coolant temperatures, fuel oil consumption) during 12-month sea practice (Sep 2024-Jul 2025). The population comprised all engine data at 70-80% stable load; purposive sampling yielded 30-50 daily observations. Instruments included ship-standard thermometers, flow meters, and tachometers, analyzed via simple linear regression (Y = 64.183 - 0.395X), Pearson correlation (r = 0.995), and ANOVA in SPSS. Results revealed significant negative correlation; 1°C coolant increase temperature reduces thermal efficiency by 0.395% (Sig. < 0.001). Conclusions recommend real-time coolant monitoring and routine maintenance to optimize fuel efficiency and engine longevity.

Keywords: *Coolant Temperature; Diesel Engine; Marine Propulsion and Thermal Efficiency.*

I. INTRODUCTION

Shipping plays a strategic role in supporting the mobility of people and goods in Indonesia as a maritime nation, so the reliability of merchant vessels is a key factor in supporting national economic performance. In ship operations, diesel main engines act as the main power source for propellers, so the stability of their performance is crucial for the safety and smooth operation of shipping. One of the vital subsystems that affects main engine performance is the freshwater and seawater cooling system, which is responsible for maintaining the engine's operating temperature within the optimal operating range, preventing overheating or overcooling that can reduce efficiency and accelerate component damage. Various recent studies have shown that intelligent and optimized cooling system management can reduce fuel consumption, increase thermal efficiency, and extend the operational life of diesel engines, including in marine applications.In the context of a ship's main engine, coolant temperature is a crucial parameter that influences the balance between the heat generated from fuel combustion and the heat released through the cooling system. Coolant temperature that is too low results in the combustion process not reaching the ideal temperature, resulting in incomplete combustion, decreased thermal efficiency, and a tendency for specific fuel consumption to increase. Conversely, coolant temperature that is too high increases the risk of overheating, causing decreased thermal efficiency, impaired performance, and potentially serious damage to key components such as cylinder liners, pistons, and head gaskets. Experimental research and thermal modeling have shown that proper temperature regulation and heat distribution through the cooling system contribute significantly to increasing the thermal efficiency of diesel engines and reducing heat loss to the coolant.

Therefore, controlling the coolant temperature in a ship's main engine is a critical issue that impacts not only technical aspects but also energy efficiency and shipping operating costs.Although the cooling system has been designed to maintain stable main engine temperatures, field practice shows that some ships still experience problems related to fluctuations in coolant water temperature and reduced cooling performance, which ultimately affects the engine's thermal efficiency. Increased coolant water temperature can be caused by various factors, including fouling in the fresh water cooler, blockages in the sea chest or filter, and decreased seawater pump performance, which results in reduced coolant flow. These conditions can cause an increase in the temperature of high-temperature components, cause uneven heat distribution within the engine, and increase heat loss that is not utilized as mechanical work. Several studies related to main engine cooling systems and seawater pumps also confirm that disturbances in the cooling system directly contribute to reduced engine performance and disrupt ship operations.On the other hand, recent research on thermal management in diesel engines has shown that adjusting the coolant temperature profile and optimizing the coolant flow rate can improve thermal efficiency and reduce fuel consumption.

Cooling system optimization approaches, such as regulating the freshwater pump speed, managing the jacket cooling water temperature, and controlling heat distribution in the high-temperature zone, have been shown to reduce fuel consumption and increase engine power efficiency. However, studies specifically linking variations in coolant temperature with changes in the thermal efficiency of main engines under real-world operating conditions on merchant ships are still relatively limited, particularly on domestic routes with varying operating characteristics. This creates a research gap that needs to be addressed through empirical studies based on main engine operation data on ships. Based on the description, this study aims to analyze the effect of cooling water temperature on the thermal efficiency of the diesel main engine on the MV PRITHA ship. Specifically, this study intends to measure and examine the relationship between variations in cooling water temperature and changes in thermal efficiency, as well as to identify the most optimal cooling water temperature range to produce the highest thermal efficiency in the main engine. The urgency of this study lies in its contribution to increasing energy efficiency and reducing fuel consumption in ship operations, which in turn has an impact on reducing operational costs and exhaust emissions. The novelty of this study lies in the application of quantitative analysis of the relationship between cooling water temperature and thermal efficiency based on real operational data of the MV PRITHA ship's main engine on domestic shipping routes, by integrating the findings of advanced diesel engine thermal management theories into the operational context of Indonesian merchant ships.

II. METHODS

This study adopts a quantitative descriptive-analytical approach that aims to analyze the causal relationship between cooling water temperature as an independent variable and the thermal efficiency of the main engine as a dependent variable on the MV PRITHA vessel. This type of research involves the direct collection of numerical data through observation and recording of operational parameters such as engine speed (RPM), inlet and outlet cooling water temperatures, and fuel consumption (FO), which are then processed statistically to test the hypothesis of a significant effect. The quantitative approach was chosen because it is suitable for measuring variable relationships objectively and generalizing findings based on empirical data, as explained by Sugiyono who emphasizes the use of numerical data and statistical analysis to test hypotheses on a specific population/sample. In addition, Creswell defines quantitative design as a strategy that relies on measuring variables and testing hypotheses through statistical procedures to explain phenomena. This approach is also in line with the principles of quantitative methodology that emphasizes the postpositivist paradigm to produce testable and verifiable knowledge.Primary data collection instruments include direct measurements using standard ship equipment such as a digital thermometer for cooling water temperature, a flow meter for flow rate, a tachometer for RPM, and a fuel flow meter for FO consumption, while secondary data are obtained from the engine log book and the main engine manual book.

Data analysis techniques include a simple linear regression test to measure the effect of cooling water temperature on thermal efficiency (with the equation $Y = a + bX$), a Pearson correlation test to assess the strength and direction of the relationship (r close to 1 indicates a strong positive/negative correlation), and an ANOVA test to confirm the significance of the model (Sig. < 0.05) using SPSS software. This technique allows the identification of relationship patterns, such as a negative regression coefficient indicating that increasing cooling water temperature decreases thermal efficiency, as recommended by Sudaryono in quantitative data analysis for engineering research. Emzir added that this kind of numerical analysis must be systematic to ensure the validity and reliability of the results.The study population is all operational data of the cooling system and thermal efficiency of the 6-cylinder diesel main engine on the MV PRITHA vessel during the 12-month sea practice (Prala) period from September 2024 to July 2025, with the main location in the ship's engine room while operating on domestic routes. Samples were taken purposively with the criteria of stable operating conditions (constant RPM 70-80% load), resulting in 30-50 representative daily observation data sets for regression and correlation analysis, ensuring the sample covers the natural variation of cooling water temperature.

This sample selection follows Sugiyono's principle for non-probability sampling in specific case studies where the population is limited to field objects. Creswell also supports a purposive sampling approach in quantitative designs to maximize the relevance of data to research variables.The research procedure begins with problem identification based on field observations, followed by primary data collection through systematic observations during main engine operation and secondary data collection from ship documents. Next, the data are validated through prerequisite tests (normality, linearity), analyzed using linear regression and Pearson correlation via SPSS, and interpreted to test the hypothesis H0 (no effect) versus H1 (significant effect). The process concludes with a discussion of the results against thermal efficiency theory and practical recommendations, following a systematic quantitative framework as outlined by Sudaryono and Emzir to ensure a logical flow from data collection to conclusions. This approach ensures the comprehensiveness and replicability of the research, in line with Creswell's research design which emphasizes the integration of data collection-analysis-interpretation procedures.

III. RESULT AND DISCUSSION

Overview of Research Location

This research was conducted during the researcher's PRALA (Sea Practice) from September 15, 2024, to July 19, 2025, on the MV Pritha. The research was conducted in the ship's engine room, with the main engine as the ship's primary propulsion system. The main engine observed was a diesel engine equipped with a water cooling system to maintain optimal operating temperatures.

Based on the results of the analysis prerequisite tests that have been conducted, the research data is declared suitable for further analysis using two methods. The methods are as follows:

1. **Simple Linear Regression Test**

Table 1. Regression Test Results

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	64.183	.657		97.764	<.001
	suhu air pendingin	-.395	.009	-.995	-42.222	<.001

a. Dependent Variable: efisiensi termal

From the data above it can be concluded:

Y : constant value – cooling water temperature, Y : 64.183 – 0.395X

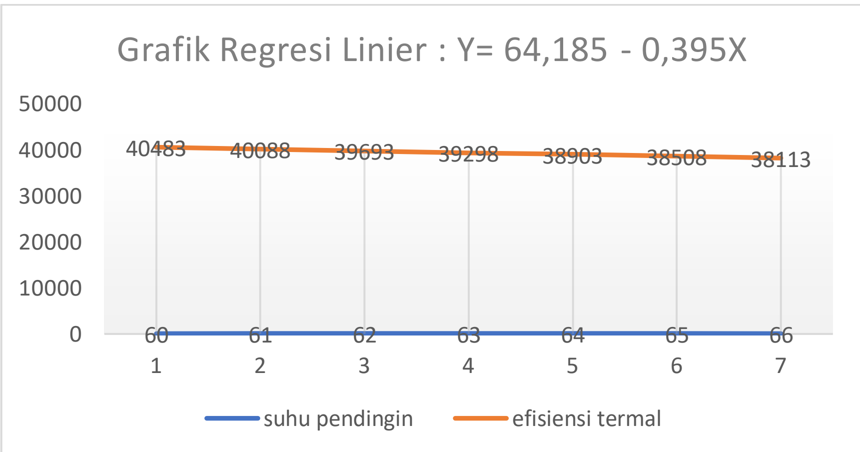

Fig 1. Linear Regression Graph

Source: Researcher Document

A coefficient value of -0.395 indicates that for every 1°C increase in cooling water temperature, thermal efficiency will decrease by 0.395%, assuming other variables remain constant. The negative sign indicates an inverse relationship. That is, an increase in cooling water temperature equals a decrease in thermal efficiency, and vice versa, a decrease in cooling water temperature increases thermal efficiency. A constant value of 64.183 indicates the thermal efficiency of the main engine under baseline conditions, when the coolant temperature is assumed to be constant or unchanged. This is the level of thermal efficiency the engine can achieve under ideal operating conditions, when the coolant temperature has not yet affected the heat transfer process within the engine. Thermal efficiency is determined by an engine's ability to convert the heat energy generated by fuel combustion into mechanical energy. Under optimal cooling conditions, excess heat can be released in a controlled manner, keeping the engine's operating temperature within limits. A significance value (Sig.) of 0.001 means that the chance of the research results occurring by chance is very small, at a significance level of 0.05 (probability value). Therefore, the statistical test results can be declared significant.< Therefore, the hypothesis stating that there is no effect is rejected. The effect of cooling water temperature on thermal efficiency is accepted. $H_0 H_1$

2. Correlation Test

Table 2. Results of the SPSS Correlation Test

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.995[a]	.990	.989	.25102

a. Predictors: (Constant), suhu air pendingin

Source: Researcher Document

The r value is 0.995, indicating a strong positive correlation. Therefore, if variable x increases, variable y will also increase, and if variable x decreases, variable y will also decrease.

Data analysis

1. Quantitative Analysis Results

A correlation value approaching one indicates a very close relationship between the variables. Linear regression indicates that changes in the coolant variable are strongly associated with changes in thermal efficiency. This aligns with internal combustion engine theory, which states that the cooling system maintains optimal thermal conditions for efficient combustion and minimizes energy loss.Coefficients indicating a negative coolant temperature regression coefficient provide a theoretical explanation for the direction of this relationship. Increasing coolant temperature reduces the cooling system's ability to absorb heat from the engine, thereby increasing engine temperature.

Discussion

In this discussion, the results of the analysis of the two research results will be explained.

1. Problem formulation 1

Based on the model summary results, a correlation value of 0.995 indicates a very strong relationship between coolant temperature and diesel engine thermal efficiency. This relationship demonstrates that coolant temperature plays a central role in regulating engine thermal conditions. Coolant temperature maintains engine component temperatures within standard operating limits. Therefore, changes in coolant temperature directly affect the heat balance within the engine and its thermal efficiency.The coefficient of determination value of 0.990 shows that all variations in thermal efficiency can be explained by changes in the cooling water temperature. This indicates that the cooling water temperature is the key to controlling the thermal performance of the engine.In the thermodynamic theory of a main engine, thermal efficiency is determined by the ratio of the heat energy produced by fuel combustion to the mechanical energy produced by the engine. When the cooling system operates effectively at the correct temperature, the heat generated by combustion can be controlled, thus minimizing heat loss and optimal energy utilization.The negative relationship shown by the regression model indicates that increasing coolant temperature is inversely proportional to the thermal efficiency of the main engine. Increasing coolant temperature reduces the coolant's ability to absorb heat. Theoretically and based on Model Summary data, coolant temperature has a very strong and dominant influence on the thermal efficiency of a diesel engine. This relationship confirms that controlling the coolant temperature at an optimal value is a crucial factor in maintaining the performance and thermal efficiency of a diesel engine, and supports the basic principles of thermodynamics and engine cooling system theory.

2. Problem formulation 2

Table 3. Spps Results

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	112.331	1	112.331	1782.712	<.001[b]
	Residual	1.134	18	.063		
	Total	113.466	19			

a. Dependent Variable: efisiensi termal

b. Predictors: (Constant), suhu air pendingin

Source: Researcher's document

Based on the ANOVA table, the F value obtained was 178.712 with a significance value <0.001. In the regression test, it was used to determine the significant effect on the cooling water temperature. A sig. value smaller than 0.005 indicates that the probability of error in concluding the effect of cooling water. The very large calculated F value (1782.712) indicates that the Mean Square Regression is much larger than the Mean Square Residual. This means that the variation in the thermal efficiency of the main engine that can be explained by the regression model is much larger than the variation originating from measurement errors or other factors outside the model. In other words, the cooling water temperature has a very dominant role in explaining changes in the thermal efficiency of the main engine.Furthermore, when viewed from the distribution of data variations, the Sum of Squares Regression value is much larger than the Sum of Squares Residual, indicating that most of the variation in total thermal efficiency comes from the influence of cooling water temperature. This confirms that the relationship shown by the regression model is not a coincidence, but rather a real and statistically strong relationship.It can be confidently concluded that coolant temperature significantly affects the thermal efficiency of the main engine. The regression model used is statistically significant and suitable for explaining and predicting changes in the main engine's thermal efficiency based on variations in coolant temperature.

IV. CONCLUSION

This study concludes that the cooling water temperature has a significant and negative effect on the thermal efficiency of the diesel main engine on the MV PRITHA, as evidenced by a simple linear regression test with a coefficient of -0.395 (Sig. < 0.001) and a Pearson correlation of r = 0.995 indicating a very strong relationship. Every 1°C increase in cooling water temperature causes a decrease in thermal efficiency of approximately 0.395%, with a constant value of 64.183% at optimal conditions, while the ANOVA test (F = 178.712; Sig. < 0.001) confirms the statistical significance of the model. These findings confirm that controlling the cooling water temperature within the optimal range is crucial to maximize the conversion of combustion energy into mechanical work, reduce heat loss, and improve engine operational performance during domestic shipping.

Although the analysis results show a robust regression model with $R^2 = 0.990$, limitations of the study include the focus on a single vessel (MV PRITHA) with stable operating conditions of 70-80% load, so generalization to other vessels or variable loads requires further validation; the data also relies on field measurements that are susceptible to external factors such as seawater quality. Practical implications include recommendations for ship engineers to monitor cooling water temperatures in real-time through automation systems, perform routine maintenance on fresh water coolers and sea chests to prevent fluctuations, and optimize pump flow rates to save fuel by 5-10% and reduce emissions. Suggestions for further research include integrating CFD simulations to model 3D heat distribution, comparing multiple vessels, and exploring nano-fluid cooling to improve heat transfer in tropical Indonesia.

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