

# The Effect of Injector Performance on Exhaust Gas Temperature Diesel Generator Engine on Ship

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## Abstract.

*Injectors play a crucial role in optimal combustion of marine diesel generator engines, but their performance degradation often causes exhaust gas temperature fluctuations that reduce efficiency and operational reliability. This study aims to analyze the effect of injector performance on exhaust gas temperature on the SV. STELLA 28 vessel. Using a causal descriptive quantitative approach, the population is operational data of Auxiliary Engine 1 and 2 for 12 months, with a purposive sample of 70 observations. Instruments include injector maximum pressure (P<sub>MAX</sub>) measurements and exhaust gas temperature thermocouples, analyzed through the Kolmogorov-Smirnov normality test, simple linear regression, and SPSS. The results show a significant effect (Sig. 0.000) with R<sup>2</sup> 0.417 and the equation . The conclusion states that optimal injector performance stabilizes exhaust gas temperature, supporting condition-based maintenance.  $Y = 31,920 + 6,153X$*

**Keywords:** Diesel Engine; Exhaust Gas; Injector Performance; Linear Regression and Marine Generator.

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## I. INTRODUCTION

The increasing market demand in the maritime transportation sector for goods mobility and transportation services requires not only having a large number of vessels, but also maintaining them in good condition and ready to operate. To achieve this, planned maintenance and repairs are required for all ship machinery and equipment, as well as compliance with the rules and policies set by the company. The smooth operation of the ship is highly dependent on the condition of the main engine, so routine and scheduled maintenance on all parts of the main engine is very important to ensure its optimal performance [1] Modern maritime transportation relies heavily on the reliability of diesel engines as prime movers and as a source of electrical power through diesel generators, making the quality of the combustion process a key factor in the safety and efficiency of ship operations [2][3]. In this system, injectors play a crucial role in converting liquid fuel into a fine mist at high pressure to achieve optimal air-fuel mixing and near-perfect combustion [4][5]. Various studies have shown that disturbances in the spray pattern, opening pressure, or nozzle cleanliness can trigger incomplete combustion, increased emissions, and significant changes in exhaust gas temperature, which is one of the main indicators of diesel engine operating conditions [6]. In marine diesel generator engines, fluctuations in exhaust gas temperature between cylinders have the potential to reduce efficiency, accelerate component damage, and increase the risk of engine failure during continuous shipping operations [7].

On the other hand, exhaust gas temperature monitoring has been widely used as a non-invasive diagnostic method for early detection of injector performance degradation and combustion process anomalies in diesel engines [8]. The development of thermal models and exhaust gas temperature-based condition monitoring approaches has shown that small variations in fuel injection characteristics can be interpreted as systematic changes in exhaust gas temperature in each cylinder, thus enabling predictive maintenance [9]. However, most of these studies have focused on stationary diesel engines or automotive applications, while quantitative studies specifically linking injector performance with exhaust gas temperature in marine diesel generator engines, especially in the context of real-world operations during shipping, are still relatively limited [10]. This situation emphasizes the importance of research that examines the relationship between injector performance and exhaust gas temperature in marine diesel generator engines using representative field data [11]. Observations during sea practice on the SV. STELLA 28 ship showed that the diesel generator engine operated an average of 15–18 hours per day with high loads and limited downtime, so that the fuel system components, especially the injectors, worked under severe thermal and mechanical conditions [6].

Under these operating conditions, variations in exhaust gas temperature between cylinders were recorded which became more pronounced as the engine operating duration increased, indicating that the fuel injection pattern was no longer uniform, resulting in less than perfect combustion [12]. After periodic maintenance such as cleaning or adjusting the injectors, the exhaust gas temperature tended to return to stability and more even, thus empirically indicating that the decline in injector performance was correlated with the increase and instability of exhaust gas temperature [13]. Although several studies have addressed the effect of fuel atomization quality on exhaust gas temperature in both main engines and dual fuel diesel engines, most have focused on descriptive aspects or specific fault cases without quantifying the strength of the statistical relationship between injector performance parameters and exhaust gas temperature [8]. Furthermore, studies specifically using injector performance parameters (e.g., peak combustion pressure reflecting injection quality) as independent variables and marine diesel generator engine exhaust gas temperature as the dependent variable in a regression model are still rare in the recent literature [10]. These limitations make it difficult for practitioners on board ships to establish evidence-based operational limits when interpreting exhaust gas temperature changes as an indication of injector degradation, resulting in maintenance actions often being performed reactively and not fully supported by quantitative analysis [7].

Thus, the main problem formulation in this study is whether injector performance significantly affects the exhaust gas temperature of diesel generator engines on ships, and how strong the relationship is between the two variables in real operating conditions [11]. Based on this description, this study aims to: (1) analyze the effect of injector performance on the exhaust gas temperature of diesel generator engines on ships, and (2) measure the strength of the relationship between the two quantitatively using a simple linear regression approach based on field data from the SV. STELLA 28 ship [6]. Practically, the results of this study are expected to provide a scientific basis for the preparation of a more measurable injector maintenance strategy by utilizing exhaust gas temperature as a performance indicator, so as to improve engine reliability, reduce the risk of damage, and support ship operational efficiency [13]. The urgency of this research lies in the need for the shipping industry to have a simple but reliable monitoring method in identifying declines in injector performance through routinely measured parameters, namely exhaust gas temperature, without having to rely on expensive diagnostic equipment [8]. The novelty of this research lies in the statistical modeling of the relationship between injector performance and exhaust gas temperature in marine diesel generator engines based on real operational data during long-term marine practice, which integrates the technical perspective of the fuel injection system with engine thermal indicators to support the implementation of condition-based maintenance in the maritime environment [10].

## II. METHODS

### Types and Methods of Research

This study uses a quantitative approach with a causal descriptive design to examine the effect of injector performance as an independent variable on exhaust gas temperature as a dependent variable in the SV. STELLA 28 ship diesel generator engine. The quantitative approach was chosen because it allows objective numerical measurement of primary data through direct observation and statistical analysis to test the causality hypothesis, in accordance with the definition [14] which emphasizes the use of formal instruments and hypothesis testing based on the philosophy of positivism. The causal descriptive design is also relevant to describe the linear relationship between variables while explaining the mechanism of their influence [15] within an explanatory research framework that integrates the description of phenomena with causal testing. This approach is in line with the practice of diesel engine engineering research on ships, where field data such as injector maximum pressure (P<sub>MAX</sub>) and exhaust gas temperature are analyzed to support predictive maintenance.

### Data Analysis Instruments and Techniques

The primary data collection instrument was direct measurement of injector performance (P<sub>MAX</sub> pressure) and exhaust gas temperature using thermocouples on six cylinders of each Auxiliary Engine 1 and 2, supported by secondary data from the ship's log book and manual book. The collection technique included quantitative observation, documentation, and literature study to ensure the validity of the numerical data

collected during 12 months of sea practice, in accordance with recommendations [14] for quantitative research that relies on precision measuring instruments. Data analysis was carried out in stages with the Kolmogorov-Smirnov normality test, linearity test, simple linear regression ( $Y = a + bX$ ), coefficient of determination ( $R^2$ ), and hypothesis t-test using SPSS [16] to verify statistical assumptions and measure the strength of influence. This approach allows for comprehensive interpretations such as the 41.7% contribution of injector performance to exhaust gas temperature variations, consistent with the methodology [17] which emphasizes the integration of assumption testing and causal models in engineering research.

### Population and Sample

The research population consists of all operational data of diesel generator engines (AE1 and AE2) of the SV. STELLA 28 vessel during sea practice, including injector PMAX measurements and exhaust gas temperatures on six cylinders per engine that reflect real working conditions at sea. Samples were taken purposively as many as 35 observations per engine (a total of 70 data) with a mean value that represents the population, according to the formula [14] for representative samples from an infinite population in field research. This sample selection ensures generalization to similar vessel operations, [15] suggesting a causal design that prioritizes empirical data from natural settings. The purposive sampling technique is also in line with maritime research practices where samples are limited by field access, but remains valid for statistical inference such as regression tests.

### Research Procedures

The research procedure began with initial observations during sea practice on board the SV. STELLA 28 to identify exhaust gas temperature variations related to injector performance, followed by primary data collection through daily measurements of PMAX and engine cylinder temperatures during operational loads of 15–18 hours/day. Secondary data from logbooks and manuals were compiled together, then processed with SPSS for prerequisite tests (normality, linearity) before regression and hypothesis analysis, following systematic steps. Validation was performed through source triangulation and engineer consultation, ensuring reliability suitable for quantitative research using SPSS. The process concluded with interpretation of results for maintenance recommendations, in line with the causal research cycle that emphasizes iteration from collection to evidence-based conclusions.

## III. RESULT AND DISCUSSION

### Result

#### Analysis of Research Variables

##### 1. Injector Performance (X)

Injector performance is a critical component in a diesel engine's combustion system, regulating fuel injection. In this study, injector performance was used as the independent variable (X), measured by maximum pressure. The average injector performance on the SV. Stella 28 is as follows:

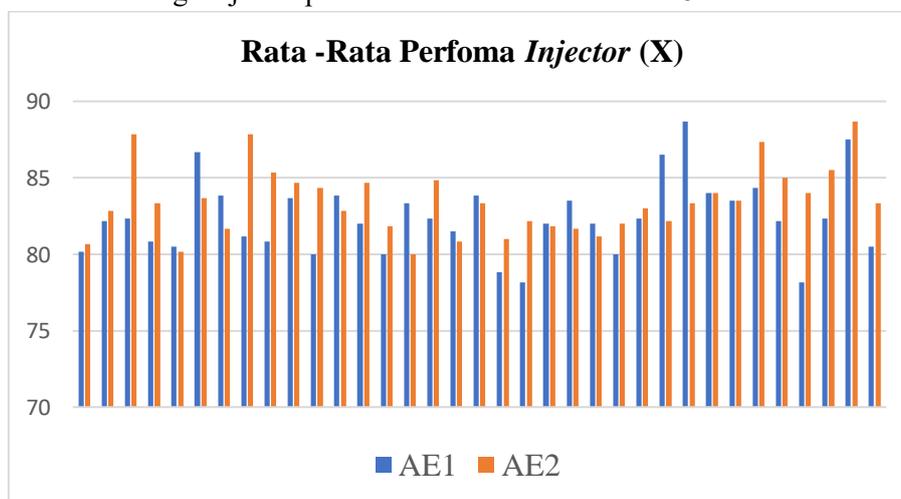


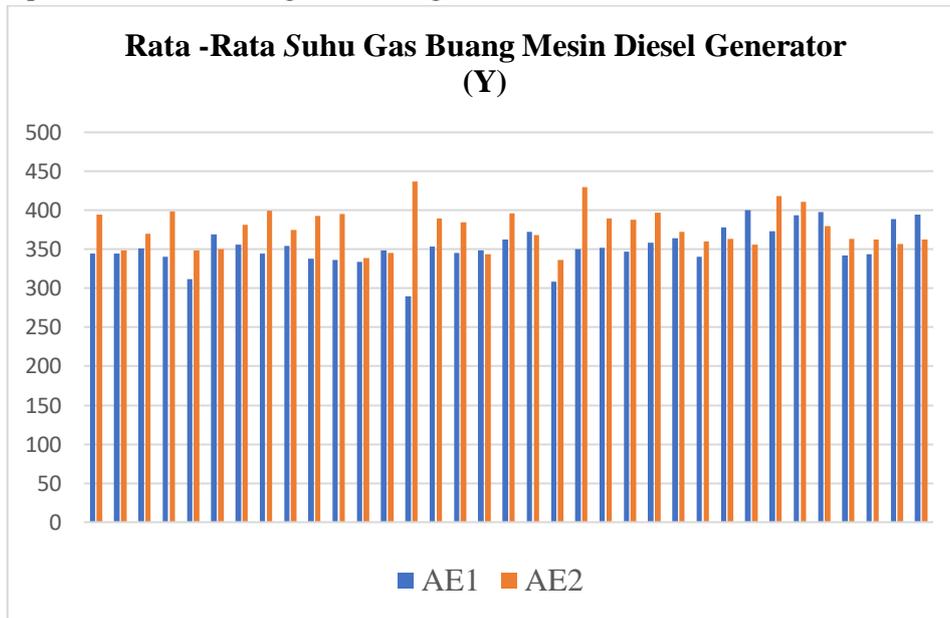
Fig 1. Average Injector Performance of the SV. Stella 28 Ship

Source: Primary data processing, 2025

Figure 1 shows the average injector performance on the SV. Stella 28 vessel, assessed based on the maximum combustion pressure (P<sub>MAX</sub>) on two diesel generator engines, AE1 and AE2. The measurement results show that the P<sub>MAX</sub> value on both engines is in the range of around 78-89, indicating that the combustion process in the cylinder is still running well and stable. From these results, it can be seen that AE2 generally has a higher and more stable P<sub>MAX</sub> value than AE1. This condition indicates that the injector on AE2 works more optimally in spraying fuel, thus producing better maximum combustion pressure. Meanwhile, AE1 shows a more varied change in P<sub>MAX</sub> value, although under certain conditions it can reach the highest value. In general, the P<sub>MAX</sub> value on both engines is still within the permissible limits, so the injector performance is still considered adequate to support the operation of the ship's diesel engine.

**2. Diesel Generator Engine Exhaust Gas Temperature (Y)**

Diesel generator engine exhaust gas temperature is an important indicator for assessing combustion performance and efficiency. A stable exhaust gas temperature indicates proper combustion, while excessively high temperatures can indicate problems with the combustion system or engine components. The average exhaust gas temperature of the diesel generator engine on the SV Stella 28 is as follows:



**Fig 2.** Average Exhaust Gas Temperature of the SV. Stella 28 Diesel Engine

Source: Primary data processing, 2025

Figure 2 illustrates the average exhaust gas temperature of the diesel generator engines on the SV. Stella 28 vessel, measured on diesel generator engines, namely AE1 and AE2. From the measurement results, the exhaust gas temperature of both engines is in the range of around 300°C to 420°C, indicating that the combustion process in the engine is still running normally. The observation results show that AE2 tends to produce a higher exhaust gas temperature than AE1. This indicates that combustion in AE2 is more intense. Meanwhile, AE1 shows a relatively more stable exhaust gas temperature, although under certain conditions there is an increase in temperature. Overall, the exhaust gas temperature in both engines is still within safe limits.

**Normality Test**

The normality test was used to determine whether the injector performance data (X) and the exhaust gas temperature of the ship's diesel generator engine (Y) were normally distributed using the Kolmogorov-Smirnov test. The results of the normality test for the research variables are presented in the following table:

**Table 1.** Normality Test Results

<i>One-Sample Kolmogorov-Smirnov Test</i>	
<i>Unstandardized Residual</i>	
<i>N</i>	35
<i>Normal Parameters,b</i>	<i>Mean</i>
	<i>Standard Deviation</i>
	.0000000
	13.40462203

<i>Most Extreme Differences</i>	<i>Absolute</i>		.089
	<i>Positive</i>		.074
	<i>Negative</i>		-.089
<i>Test Statistics</i>			.089
<i>Asymp. Sig. (2-tailed)<sup>c</sup></i>			.200d
<i>Monte Carlo Sig. (2-tailed)<sup>e</sup></i>	<i>Sig.</i>		.679
	<i>99% Confidence Interval</i>	<i>Lower Bound</i>	.667
		<i>Upper Bound</i>	.691
<i>a. Test distribution is Normal.</i>			
<i>b. Calculated from data.</i>			

Source: Primary data processing, 2025

Based on Table 1, the results of the normality test using the One-Sample Kolmogorov–Smirnov Test show an Asymp. Sig. (2-tailed) value of 0.200, which is greater than 0.05. This indicates that the data is normally distributed. Thus, the assumption of normality in this study This has been fulfilled and the data can be used for further statistical analysis.

**Simple Linear Regression Analysis**

Simple linear regression analysis was used to determine the direction and magnitude of the influence of the independent variable (injector performance) on the dependent variable (diesel generator engine exhaust gas temperature). The results of this study's simple linear regression analysis are presented in the following table:

**Table 2.** Results of Simple Linear Regression Analysis

<i>Coefficients<sup>a</sup></i>						
<i>Model</i>		<i>Unstandardized Coefficients</i>		<i>Standardized Coefficients</i>	<i>t</i>	<i>Sig.</i>
		<i>B</i>	<i>Std. Error</i>	<i>Beta</i>		
1	(Constant)	31,920	105,136		.304	.763
	Injector Performance (X)	6,153	1,268	.645	4,854	.000

a. Dependent Variable: Diesel Engine Exhaust Gas Temperature (Y)

Source: Primary data processing, 2025

Based on table 4. the results of the simple linear regression analysis, the following regression equation is obtained:

$$Y = 31,920 + 6,153 X$$

From the equation above it can be explained that:

- a) The constant (a) of 31.920 shows that if the injector performance is constant or does not change (X = 0), then the exhaust gas temperature of the diesel engine is 31.920°C.
- b) The regression coefficient (b) of 6.153 shows that every one unit increase in injector performance will increase the exhaust gas temperature of the diesel generator engine by 0.513.°C.

**Linearity Test**

The linearity test was conducted to determine whether there is a linear relationship between injector performance (X) and the exhaust gas temperature of the diesel generator engine (Y) so that regression analysis can be used appropriately to test the effect of injector performance on the exhaust gas temperature of the diesel engine. The results of the linearity test are as follows:

**Table 3.** Linearity Test Results

<b>ANOVA Table</b>							
			Sum of Squares	df	Mean Square	F	Sig.
Diesel Engine Exhaust Gas Temperature (Y) * Injector Performance (X)	Between Groups	(Combined)	10030.834	30	334,361	3,043	.144
		Linearity	4361.125	1	4361.125	39,688	.003
		Deviation from Linearity	5669.709	29	195,507	1,779	.308
	Within Groups		439,543	4	109,886		
	Total		10470.377	34			

Source: Primary data processing, 2025

Table 3 shows the results of the linearity test of the relationship between injector performance (X) and diesel engine exhaust gas temperature (Y). The significance value in the Linearity row of 0.003 ( $<0.05$ ) indicates that the relationship between the two variables is linear. In addition, the significance value in the Deviation from Linearity row of 0.308 ( $>0.05$ ) indicates there is no significant deviation from the linear pattern. Thus, it can be concluded that the relationship between injector performance and diesel engine exhaust gas temperature is linear.

#### Coefficient of Determination Test

The coefficient of determination test was conducted to determine the contribution of the independent variable (injector performance) to the dependent variable (diesel generator engine exhaust temperature). The coefficient of determination ( $R^2$ ) value indicates the proportion of the dependent variable's variation that can be explained by the independent variables in the regression model. The results of the coefficient of determination test for the research variables are presented in the following table:

**Table 4.** Results of the Determination Coefficient Test

Model Summary				
Model	R	R Square	Adjusted R Square	Standard Error of the Estimate
1	.645a	.417	.399	13.60621
a. Predictors: (Constant), Injector Performance (X)				
b. Dependent Variable: Diesel Engine Exhaust Gas Temperature (Y)				

Source: Primary data processing, 2025

Based on table 4, the results of the coefficient of determination test, the R value was obtained at 0.862 and R Square at 0.417. This means that 41.7% of the variation in changes in the exhaust gas temperature of the diesel generator engine can be explained by the injector performance variable, while the remaining 58.3% is influenced by other variables outside the study.

#### Hypothesis Testing

The t-test was used to determine the extent to which injector performance (X) partially affects the exhaust gas temperature of a diesel generator engine (Y). The results of this research hypothesis test are presented in the following table:

**Table 5.** Hypothesis Test Results

Coefficients <sup>a</sup>						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	31,920	105,136		.304	.763
	Injector Performance (X)	6,153	1,268	.645	4,854	.000

a. Dependent Variable: Diesel Engine Exhaust Gas Temperature (Y)

Source: Primary data processing, 2025

Table 5 shows the results of the hypothesis test of the effect of injector performance (X) on the exhaust gas temperature of a diesel engine (Y). The significance value (Sig.) is 0.000 ( $<0.05$ ), which indicates that injector performance has a significant effect on the exhaust gas temperature of a diesel engine. Thus, it can be concluded that  $H_0$  is rejected and  $H_1$  is accepted. This means that injector performance has a significant effect on the exhaust gas temperature of a diesel generator engine.

#### Discussion

##### The Effect of Injector Performance on Diesel Generator Engine Exhaust Gas Temperature

The results of this study show a significance value of  $0.000 < 0.05$ , so it can be concluded that the alternative hypothesis ( $H_1$ ) is accepted, which means that injector performance has a significant effect on the exhaust gas temperature of the diesel generator engine on the SV. STELLA 28 ship. This means that the better the injector performance, the more stable the exhaust gas temperature of the diesel generator engine produced. An optimally working injector is able to spray fuel with the right pressure, fine particles, and even distribution so that the combustion process takes place perfectly. This efficient combustion will keep the exhaust gas temperature at a normal and balanced level between the engine cylinders. With a stable temperature, the engine can work optimally without the risk of overheating which can interfere with performance and cause damage. Conversely, if injector performance decreases, for example due to

inappropriate pressure or blockage, combustion will be less perfect. This will cause the exhaust gas temperature to rise and the engine will not work efficiently, which in turn can accelerate wear and damage to the engine. These findings are supported by field observations conducted during the Sea Practice (Prala) activity, where researchers used data from the harbormaster's logbook from June 2024 on the SV. STELLA 28 vessel as a basis for observations.

The logbook recorded data on engine running hours, fuel consumption (gas oil), and engine opening and closing times for each Auxiliary Engine (AE) unit. Based on these records, variations in fuel consumption and exhaust gas temperature were observed, which were related to injector performance conditions. When the injector is operating optimally, namely with the correct opening pressure and smooth fuel injection, the combustion process in the cylinder chamber is more perfect, so that exhaust gas temperatures tend to be stable and engine efficiency increases. Conversely, when injector performance decreases due to wear or clogging, combustion becomes uneven, fuel is not fully burned, and exhaust gas temperatures increase. These findings are consistent with those stating that injection parameters such as injector opening pressure and nozzle condition significantly influence combustion efficiency and exhaust emissions in diesel engines. Changes in injection pressure can improve combustion quality by producing a finer and more even fuel spray, resulting in more stable exhaust gas temperatures and increased engine efficiency. However, if injector performance decreases due to low injection pressure or nozzle blockage, combustion will be suboptimal, resulting in increased exhaust gas temperatures and decreased engine performance.[18]

#### **Relationship between Injector Performance and Diesel Generator Engine Exhaust Gas Temperature**

Based on the results of the linearity test that has been conducted, it is known that the relationship between injector performance (X) and the exhaust gas temperature of the diesel generator engine (Y) is linear. This is evidenced by the significance value in the Linearity section of 0.003, which means that the value is smaller than the significance limit of 0.05. This means that changes in injector performance have a unidirectional and consistent relationship with changes in the exhaust gas temperature of the diesel engine. The better the injector performance in channeling and spraying fuel, the more stable the exhaust gas temperature tends to be. Conversely, if injector performance decreases for example due to low injection pressure, clogged nozzles, or uneven fuel distribution, the combustion process becomes imperfect. As a result, some of the fuel does not burn properly which can cause the exhaust gas temperature to become unstable and decrease engine efficiency.

#### **IV. CONCLUSION**

This study concludes that injector performance has a significant effect on the exhaust gas temperature of the diesel generator engine on the SV. STELLA 28 ship, with a significance value of 0.000 and a determination coefficient of  $R^2$  of 0.417, which indicates a 41.7 percent contribution to the variation of exhaust gas temperature, while the rest is influenced by other factors. The relationship between the two is linear as evidenced by the linearity test with a significance of 0.003, where increasing the maximum pressure (P<sub>MAX</sub>) of the injector results in a more stable exhaust gas temperature through optimal combustion, as summarized in the regression equation.

This finding confirms the hypothesis that optimal injectors reduce the risk of overheating and improve ship operational efficiency.  $Y = 31,920 + 6,153X$ . However, limitations of this study lie in the purposive sampling of 70 data sets from two engines over 12 months, which may underrepresent variations in extreme sailing conditions or alternative fuel types, and the reliance on field measurements without in-depth CFD simulations. Suggestions for further research include expanding the sample to different main engines, integrating exhaust emission variables, and long-term testing with real-time sensors for predictive modeling. Practically, these results recommend exhaust gas temperature monitoring as an indicator of condition-based maintenance injectors, thus supporting engine reliability, reducing maintenance costs, and safer and more efficient ship operations.

## REFERENCES

- [1] Prayogi, SB, Zainuddin, M., Yudianto, PY, Prawoto, A., Robbi, SD, & Nugroho, A. (2025). Analysis of the effect of declining injector performance on main engine performance in MV. *Oriental Ruby. Research Integrity and Global Growth Studies*, 4(2), Article 864. <https://doi.org/10.31004/riggs.v4i2.864>
- [2] Firman Nanda Irawan. (2023). Analysis of diesel engine reliability in ship operations.
- [4] Armstrong. (1981). Fuel-injection technology: Diesel engine. The Macmillan Company.
- [3] Kusuma, et al. (2024). Analysis of combustion efficiency of diesel generator engines on merchant ships.
- [5] George. (1995). Diesel engine combustion and injection systems.
- [6] Hilmi. (2020). Analysis of the increase in exhaust gas temperature of the diesel main engine on the MV. DK 02. Semarang Maritime Polytechnic. [http://repository.pip-semarang.ac.id/5957/2/572011217633T\\_SKRIPSI\\_OPEN\\_ACCESS.pdf](http://repository.pip-semarang.ac.id/5957/2/572011217633T_SKRIPSI_OPEN_ACCESS.pdf)
- [7] Agung Nugroho. (2014). Analysis of marine diesel engine combustion performance against variations in exhaust gas temperature.
- [8] Cahyo, SW (2016). Condition monitoring of exhaust gas temperature as an indicator of injector degradation in ship diesel generator engines. Surabaya or Semarang Maritime Polytechnic. <http://repository.polteknepel-sby.ac.id/id/eprint/739/>
- [9] Suryanto, et al. (2023). Exhaust gas temperature monitoring model for predictive maintenance of diesel engines.
- [10] Amrie Mucta. (2015). Analysis of the influence of the injection system on the performance of ship diesel generator engines.
- [11] Dynamic Journal. (2020). Study of the effect of the combustion system on the exhaust gas temperature of marine diesel engines.
- [12] Herlina, Pratama, & Waspodo. (2019). Observing the decline in the performance of the main motor injector on the KM. Zaisan Star II ship, PT. Zaisan Citra Mandiri. *Journal of Maritime Transportation Science and Technology*, 1(1), 1–9. <https://doi.org/10.51578/j.sitektransmar.v1i1.7>
- [13] Sariffudin, Widada, & Hase. (2021). Analysis of the decline in injector performance on the combustion process of diesel engines on ships. *E-Journal Marine Inside*, 3(2), 31–42. <https://doi.org/10.56943/ejmi.v3i2.32>
- [14] Widopo Cahyo. (2016). Analysis of exhaust gas temperature as an indicator of combustion disturbances in marine diesel engines.
- [14] Sugiyono. (2022). Quantitative, qualitative, and R&D research methods. Alfabeta.
- [15] Creswell, J. W., & Creswell, J. D. (2022). Research design: Qualitative, quantitative, and mixed methods approaches (6th ed.). Sage Publications.
- [16] Sudaryono. (2023). Quantitative, qualitative, and mixed method research methodology. RajaGrafindo Persada.
- [17] Emzir. (2021). Educational research methodology: Quantitative and qualitative. Rajawali Pers.
- [18] Ardhiyansah, W., Wanto, A., Frastika, R., Saifudin, & BTR. (2025). The effect of decreasing injector performance on the performance of the main engine on the MV. SAVIOUR. *Journal of Marine Engineering Research*, 1(1), 11–23.