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Investigation of High Exhaust-Gas Temperature in Cylinder No. 2 of the Main Engine on KM. Rucitra VII

I Putu Adhitya Yastra Pramana[1], Imam Safi'i[2], Riyandini Utari[3,*]

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ABSTRACT

In the combustion system, the exhaust gas temperature plays a crucial role in the diesel engine's performance. If one of the Exhaust gas temperatures rises, it can impact the engine's condition. A decline in the engine's performance, particularly in the main engine, will affect the ship's operation. The research was prepared to investigate the factors, impacts, and efforts of the high exhaust gas temperature of cylinder no.2 in the main engine. This research was processed using a qualitative descriptive method using Miles and Huberman's data analysis techniques. The results showed that the factors that caused the high exhaust gas temperature of cylinder no.2 in the main engine were a decrease in the performance of the injector and the condition of the scavenging air chamber channel of cylinder no.2 in the main engine so that it had an impact on incomplete combustion which made the main engine hot which could interfere with the operation of the ship. To overcome these problems, maintenance and repair of the injector and cleaning of the rinse air chamber are carried out. With the implementation of the handling of the problem, it is expected to be able to restore the exhaust gas temperature of the no. 2 cylinder on the main engine.

1. Introduction.

According to Jusak Johan Handoyo (2015)In his book "Mesin Diesel Penggerak Utama Kapal" (Diesel Engines as the Main Propulsion for Ships), exhaust gas is the residual gas from combustion in the engine cylinder. It is the result of the work stroke that pushes the piston, thereby generating propulsive power that can move the ship at sea.

If one of the exhaust gas temperatures in a diesel engine increases, it will affect the engine's condition. One effect is that it causes heat to build up in the main engine. This heat will affect the diesel engine's performance due to an imbalance in the exhaust gas temperature in one of the cylinders, resulting in an imbalance in the performance load of the main engine. This will cause a decrease in the combustion efficiency of the engine.

Researchers experienced issues with exhaust gas temperature in the main engine during sea trials on the KM—Dharma Rucitra VII vessel. During the voyage, the duty engineer checked the exhaust gas temperature in each main engine cylinder. During the inspection, it was observed that the exhaust gas temperature of cylinder no. 2 had increased, and this observation indicated that the exhaust gas temperature of cylinder no. 2 was affecting the performance of the main engine.

If the diesel engine's performance, especially the main engine, decreases, it will affect the ship's operation. Since ships are an essential mode of sea transportation for passengers, goods, and vehicles to move from one port to another, if the ship experiences operational problems, it will affect the delivery of the cargo. The delayed delivery of cargo to the destination and the delayed loading and unloading process will ultimately reduce the quality of the ship.

Previous research on injectors in diesel engines was con-

[1]Cadet, Semarang Maritime Science Polytechnic, Semarang, Indonesia. E-mail Address: iputuadhityayastrapramana016@gmail.com.
[2]Master of Science, Semarang Maritime Science Polytechnic, Semarang, Indonesia. E-mail Address: imam@pip-semarang.ac.id.
[3]Master of Science, Semarang Maritime Science Polytechnic, Semarang, Indonesia. E-mail Address: riyadini.utari@pip-semarang.ac.id.
[*]Corresponding author: Riyandini Utari. E-mail Address: riyadini.utari@pip-semarang.ac.id.

ducted by David Sinaga & Abdilah (2023)Previous research has considered the decline in injector performance that affects combustion in diesel engines, causing one of the cylinders to experience an increase in gas temperature. This is a consideration in preparing this scientific paper.

In addition to this research, the researcher also sought references on high exhaust gas temperatures in main engines. The research conducted by Al Musyaddad & Pratama (2022) Aimed to determine the effect of injector leakage on combustion quality in diesel engines. This research discussed the suboptimal performance of injectors in the combustion system caused by a decline in injector performance, which impacted the combustion process of diesel engines.

Considering this research, the researcher was inspired to conduct research on high exhaust gas temperatures in line with the problems experienced by the author and to find ways to overcome the high exhaust gas temperatures in cylinder no. 2 of the main engine.

Based on the above background, the researcher was interested in writing a scientific paper entitled: "Analysis of High Exhaust Gas Temperature in Cylinder No. 2 of the Main Engine in KM. Dharma Rucitra VII." This research aims to investigate the factors causing high exhaust gas temperatures in cylinder no. 2 of the main engine, the impact of this problem, and the efforts made to overcome the high exhaust gas temperatures in cylinder no. 2 of the main engine on KM. Dharma Rucitra VII.

2. Research Methodology.

According to Sugiyono (2021) Research methods are scientific stages to obtain valid data for specific purposes and uses. They aim to discover, prove, and develop knowledge so that it can be used to understand, overcome, and anticipate problems.

In conducting this research, the researcher used a qualitative descriptive research method to develop the research. A qualitative descriptive research method is a method or stage carried out in conducting research. This method involves data collection using a research approach that involves descriptive and narrative descriptions, which can be used to effectively explain the research findings and convey them to the reader. The qualitative descriptive method is expected to provide an in-depth research analysis. This method focuses on the subject based on the context of meaning and experience gained, and is aimed at the subject's perspective.

This research was conducted on KM. Dharma Rucitra VII, owned by PT. Dharma Lautan Utama. The ship is a RoRo-Passenger type with a Surabaya-L.Bajo-Maumere, NTT route.

Data sources are needed to obtain research information. The data sources are divided into two types depending on how the data is obtained.

a. Primary data.
   Primary data is collected directly by the researcher for research purposes. The data obtained is pure and has not been processed by any other party. In collecting this data, the researcher uses data processing techniques appropriate to the problems encountered by the researcher.

b. Secondary data.
   Secondary data is data collected for research purposes, but the data is collected indirectly or by another party and used by the researcher in conducting the research. Secondary data collection involves scientific publications in journals, books, or research reports on the studied issue.

Data analysis is necessary for researchers to process the data found in the field to support their research. With the data analysis process, researchers can easily group the data obtained from the field into a more concise description.

The data analysis method used by the author is the data analysis method according to Miles and Huberman. The Miles and Huberman analysis method was proposed in 1984. According to Citriadin (2020) qualitative research is conducted interactively and continuously to produce saturated data. To limit the scope of this theory, several stages in this method can be used, including:

1. Data collection.
   In the first stage, data is collected using various techniques from multiple sources, such as observation, documentation, and interviews. Data collection is sourced from informants to obtain data used to support the research. This data collection focuses on the high exhaust gas temperature in the main engine.
2. Data reduction.
   Data reduction aims to reduce the information essential to the research. It is done by summarizing data or information related to the research. Data reduction involves filtering and summarizing data obtained from various sources. By performing data reduction, researchers are facilitated in separating or reducing the large amount of data received.
3. Data presentation.
   Data presentation is a stage in organizing or grouping data into a single entity. At this stage, researchers classify and present data according to the main issues. Data presentation begins with organizing data according to each main issue.
   Data presentation can take the form of tables, diagrams, or narratives. In the author's research, the data is presented in narratives obtained from various research sources based on the data collection techniques used in the study. The data presentation method facilitates research organization by grouping data according to the research discussion.
4. Conclusion or verification.
   Once the data presentation has been completed, conclusions can be drawn from it. To arrive at conclusions, it is necessary to compare the research subjects' statements with the meaning contained in the research.
   The conclusions in this research were drawn by processing the data by the data analysis method used by the researcher. The processed data was then reviewed so that conclusions could be drawn based on the issues in the research conducted by the researcher. In this case, the

researcher collected data on the factors causing the high exhaust gas temperature of cylinder no. 2 in the main engine, the impact of the high exhaust gas temperature, and the efforts made to address the high exhaust gas temperature. The conclusion was drawn to ensure consistency with the research data.

The data obtained from the field was tested for validity using the data triangulation method. According to Arianto (2024), data triangulation in a qualitative approach is often used to improve the validity and credibility of research results.

According to Sugiyono (2022) the Technical triangulation tests credibility by verifying data obtained from similar research sources using different techniques. Data triangulation strengthens the data received from the field by comparing it with previous research.

The research data was collected when the researcher observed and interviewed officers and several engineers on the researcher's ship. The data obtained was then processed according to several stages of the data analysis method. Furthermore, data was obtained from the researcher's experience conducting sea practice on the KM. Dharma Rucitra VII ship so that relevant data could be obtained to solve the problems encountered in the research.

3. Research Results and Discussion.

KM. Dharma Rucitra VII is a RoRo-passenger vessel owned by PT Dharma Lautan Utama, which is based in Surabaya, East Java. PT Dharma Lautan Utama was established in 1976 and operates throughout Indonesia. PT Dharma Lautan Utama offers several inter-island shipping routes, one of which was the vessel used during the researcher's sea project, Surabaya-L.Bajo-Maumere round trip. The ship provides good facilities and meets various needs required during the voyage.

Figure 1: KM. Dharma Rucitra VII.

Source: Personal Documents (2023).

According to Laut et al. (2022)the main engine is a machine that acts as the power source to propel the ship. According to Narto et al. (2018), the selection of a diesel engine as the main engine of a ship is a machine that works on the principle of combustion, which produces potential energy in the form of heat converted into mechanical energy.

According to Pertamina (2022) Diesel engines use a two-step principle in the combustion process. Compressed air enters through the blower side of the turbocharger into the combustion chamber, pushing the piston upward. As the piston slowly moves upward, the air is compressed, causing the combustion chamber to heat up. Fuel is then injected, triggering an explosion in the combustion chamber that pushes the piston downward. The injector component plays an essential role in the combustion process.

Figure 2: Main Engine.

Source: Personal Documents (2023).

When researchers were conducting sea project on the KM. The engineer on duty at the Dharma Rucitra VII ship checked the exhaust gas temperature of each cylinder in the main engine. During the inspection, it was observed that the exhaust gas temperature of cylinder no. 2 had increased.

Table 1: Exhaust gas data.

Cyl No.	1	2	3	4	5	6
Exhaust Temperature (°C)	360	390	360	370	365	360
Jacket Cooling Temperature (°C)	80	87	84	86	85	85
Fuel Rack	40	46	40	40	40	41

Source: Personal Documents (2023).

Observations showed that the exhaust gas temperature of cylinder no. 2 was 390°C, exceeding the recommended temperature range for the main engine, which is 310–360°C. This

deviation decreased the main engine's performance.

The duty engineer observed the main engine's exhaust gas temperature sensor and checked the fuel rack. After observing the fuel rack, it was found that the rack had increased, and the duty engineer immediately informed the 2nd Engineer about the increase in exhaust gas temperature of cylinder no. 2 in the main engine. The 2nd Engineer conducted an observation and analysis of the exhaust gas temperature. The 2nd Engineer assumed that several factors, including decreased fuel injector performance and debris in the scavenging air chamber, caused the increase in exhaust gas temperature. The 2nd Engineer planned to conduct a check when the engine stopped at L. Say Maumere Port.

When the ship docked at Maumere Port, the 2nd Engineer checked and tested the pressure on the injector components. During the inspection, the scavenging air chamber and stuffing box on cylinder no. 2 were dirty. The scavenging air chamber and stuffing box contained deposits from air scavenging residues, causing a decrease in the combustion quality of the main engine. The 2nd Engineer immediately mobilized and instructed the engine crew to thoroughly clean the scavenging air chamber of cylinder no.2 main engine and repair the injector components.

When researchers researched KM Dharma Rucitra VII, researchers found the following factors causing the main engine's high exhaust gas temperature in cylinder no.2 on the main engine.

3.1. Decreased performance of the injector.

According to Dwi Ardhiyansah et al. (2024) Testing the injector aims to determine the decrease in atomization pressure in the injector. If the injector shows a decrease in atomization, it indicates that the injector is not in good condition.

Checking the injector fogging pressure using the injector fogging pressure test tool when the ship is alongside at the port of Maumere, NTT.

Figure 3: Injector Pressure Test.

Source: Personal Documents (2023).

The decreased performance of the injector is caused by the condition of the tip of the injector nozzle dripping, resulting in incomplete combustion with a waste of fuel that produces black smoke coming out of the ship's chimney.

Based on the findings regarding the decrease in fogging pressure in the injector that which affects the high exhaust gas temperature of cylinder no.2 in the main engine, it is supported by findings based on the results of research conducted by Al Musyaddad & Pratama (2022) The research shows that diesel engines' injector fogging pressure decreases in cylinders no. 2 and no.5 due to dripping fuel in the combustion chamber, which affects the high exhaust gas temperature. The dripping fuel causes aftershock combustion, which impacts wasteful fuel consumption and the output of black smoke in the chimney, which causes environmental pollution.

The dripping of fuel at the tip of the nozzle is also supported by research conducted by David Sinaga & Abdilah (2023), which found that the condition of the injector nozzle dripping caused a decrease in fuel atomization pressure, resulting in incomplete combustion and an increase in exhaust gas temperature in diesel engines.

3.2. Dirty no.2 cylinder Scavenging air chamber duct on main engine.

When the researcher and driver inspected the scavenging air chamber, they found that the rinse air in the scavenging cylinder no. 2 was dirty. The dirt came from the accumulation of cleaning residue in the rinse air chamber. Dirty scavenging air chamber ducts can cause less clean air flushing so that it can reduce the amount of fresh air entering cylinder no.2 of the main engine. As a result, the exhaust gas is not entirely wasted, so that combustion in the next cycle is not optimal and can increase exhaust gas temperatures.

Based on some of the findings described above, researchers collected interview data from several sources, namely the 2nd and 4th Engineers who were on the ship. The results of these interviews are described in tabular form as follows.

Table 2: Interview data.

No	Source	Results of the interview
1.	2nd Engineer	According to 2nd Engineer, the causal factor of the high exhaust gas temperature of cylinder no.2 on the main engine at KM. Dharma Rucitra VII is a decrease in the performance of the fuel atomizer caused by incomplete fogging of the injector. The nozzle part of the injector drips, triggering incomplete combustion which can increase the exhaust gas temperature of cylinder No.2 on the main engine.
2.	4th Engineer	According to 4th Engineer, the factor that causes the high exhaust gas temperature of cylinder no.2 in the main engine is the presence of dirt in the rinse air chamber channel in cylinder no.2 of the main engine. The dirty rinse air chamber comes from the deposition of the remains of cleaning or flushing the compression air.

Source: Personal Documents (2023).

3.3. The impact of high exhaust gas temperature in cylinder no. 2 of the main engine.

3.3.1. Incomplete Combustion.

Incomplete combustion occurs when fuel cannot burn completely in the combustion chamber. It produces emissions in the form of carbon, which can pollute the marine environment. According to Al Musyaddad & Pratama (2022), incomplete combustion can reduce the performance of the engine and increase the exhaust gas temperature of the main engine.

Decreased performance in the injector results in incomplete combustion. The resulting fogging is less than perfect, thus affecting the combustion results. Incomplete combustion can impact the main engine, such as increased fuel consumption because the fuel does not burn properly, so the engine requires more fuel to produce the same power to move the ship.

The exhaust gas temperature of cylinder no.2 has an impact on the combustion products, as revealed by Mafrizal et al. (2022)That the fuel that is atomized in the combustion chamber cannot burn optimally, resulting in black smoke being emitted from the ship's funnel. Black smoke is caused by excess atomized fuel. Black smoke can cause carbon deposition in the combustion chamber which can reduce engine efficiency and can accelerate the wear of components in the engine.

3.3.2. Main engine heat.

Table 3: Manual Book Reference Parameter.

Parameter	Inlet/ Outlet	Normal Service Value (°C)	Max Limit (°C)	Min Limit (°C)	Slow Down (°C)		Normal Service Value (bar)		Min Limit (bar)	Slow Down (bar)	
					Slow Down	Shut Down	Normal Service Value (bar)	Max Limit (bar)		Slow Down	Shut Down
Main Bearing L.O. Engine	Inlet	40–50	55	35	-	-	1.6 < *2	1.2 *2	1.0 *2	0.8 *2	-
Piston Cooling Oil	Inlet	40–50	55	35	-	-	1.6 < *2	1.4 *2	1.4 *2	1.1 *2	-
	Outlet	50–60	70	-	70	80	-	-	-	-	-
Turbocharger L.O. (BBC TC Type)	Inlet	55–100	105	-	-	120	-	-	-	-	-
Lube Oil of Camshaft	Inlet	40–55	60	-	-	-	2.5–3.0	2.0	2.0	1.5	-
	Outlet	45–65	75	-	75	85		-	-	-	-
Fresh Water	Inlet	60<	80	60	-	-	1.6–2.6	-	-	*1) H+0.8	*1) H+0.8
Fresh Water of Turbocharger	Outlet	75–82	90	-	90	95	-	-	-	-	-
	Inlet	60 <	80	60	-	-	1.6–2.6	-	-	*1) H+0.8	-
	Outlet	75–82	90	-	90	95		-	-	-	-
Fresh Water Across Main Engine	-	-	-	-	-	-	0.6	0.4	0.2	-	-
Sea Water of Air Cooler	Inlet	-	-	10	-	-	1.0–2.0	0.5	-	-	-
	Outlet	-	50	-	-	-		-	-	-	-
Scavenging Air (After Air Cooler)	-	30–50	55	25	-	-	-	-	-	-	-
Starting Air	-	-	-	-	-	-	25–30	15	-	-	-

Notes:

*1) H = Height of Fresh Water Pump Suction (in meters)

*2) Depends on engine type and load condition.

All valves are normally open unless otherwise specified.

Source: Manual book.

High exhaust gas temperatures create uneven heat within the engine cylinder. This can result in decreased engine efficiency and power due to suboptimal combustion. Based on observations and checks of the main engine's coolant temperature, the coolant inlet temperature is 79 ℃, indicating that the main engine is in a hot state. The parameters of the main engine system are shown in the table 3.

3.3.3. The operation of the ship is delayed.

The exhaust gas temperature of cylinder no.2 in the main engine has increased due to the fuel atomized by the injector not working optimally. As a result, one of the cylinders experiences a power objection or workload imbalance in the engine. This can produce less than maximum main engine power so that the ship's speed becomes slow due to incomplete combustion.

3.4. Efforts made to overcome the high temperature of exhaust gas no.2 in the main engine.

3.4.1. Maintenance of the fuel injector.

Maintenance on injector components is very important to prevent and overcome the high temperature of the cylinder exhaust gas in the main engine. In the problem experienced by the author, the effort made was to clean and replace the nozzle part of the injector component.

According to Dwi Ardhiyansah et al. (2024) The replacement of the nozzle improves the fogging pattern in the injector so that the fogging in the injector can run smoothly and can increase the pressure of the fuel fogging according to the manual.

Performing regular maintenance and testing on the injector ensures optimal injector performance and prevents a decline in the performance of the main engine.

Figure 4: Disassembly of the injector.

Source: Personal Documents (2023).

3.4.2. Cleaning the Scavenging-Air Chamber of Cylinder No. 2.

Cleaning the scavenging air chamber on cylinder no. 2 of the main engine can lower the exhaust gas temperature of cylin-

der no. 2 of the main engine, and the clean air flow helps maintain a stable temperature in the cylinder.

Figure 5: Cleaning the scavenging air chamber of cylinder no.2 on main engine.

Source: Personal Documents (2023).

Clean the scavenging air chamber of cylinder no.2 on main engine can prevent the accumulation of air rinse residue, thereby facilitating air flow and improving engine performance. Cleaning the rinse air duct.

Conclusions.

Based on the results of the discussion of the above findings, the researcher concludes that the factors that cause the high exhaust gas temperature of cylinder no.2 in the main engine are the decreased fogging pressure of the injector and the dirty air chamber rinse cylinder no.2 in the main engine which results in incomplete combustion so that the main engine becomes overheated and slows down the operation of the ship's engine.

To overcome these problems, it is necessary to clean and replace the injector nozzle parts that have leaked and clean the rinse air chamber channel no.2 on the main engine. From the resolution of these problems, it is expected to restore the exhaust gas temperature of cylinder no.2 in the main engine to normal conditions and the ship can operate smoothly.

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