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Research Paper

Identify The Cause and Effect of Detonation in The Main Engine

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Abstract

In the process of shipping, the main engine must always be maintained in prime condition to support the smooth sailing of a ship. In the main engine, there are often oddities or things that are not common in the main engine, one of which is knocking. The purpose of this study is to identify detonation that occurs in the main engine, analyze the causes and consequences of detonation. The research method used in this research is qualitative. Sources of research data obtained from data collection techniques through observation, interviews, documentation, and data validity techniques using internal validity. The place and time of the research were conducted at MV. Tanto Hemat for one year. SWOT method to analyze various factors that can be used to optimize blasting systematically against strengths, weaknesses, opportunities, and threats. The study results identify detonation in the main engine, namely ignition delay and pre-ignition in the main engine. Factors that cause detonation in the main engine are poor fuel quality, high pressure and temperature in the engine combustion chamber, and improper combustion timing. The impact caused by detonation on the main engine is detonation will cause an increase in fuel consumption, damage to engine spare parts, and carbon buildup in the combustion chamber.

Keywords *Knocking, Detonation, Timing*

INTRODUCTION

The main engine is the most important engine in a ship for driving a ship. In the process of sailing, the main engine must always be maintained in prime condition to support the smooth sailing of a ship. On the main engine, there are often oddities or things that are not common in the main engine, one of which is knocking. Knocking often referred to as detonation, is the combustion process in the engine that is not on time, namely the fire that suddenly becomes large in the combustion process, so that the combustion process is not perfect. For the cause itself, knocking has several things that can cause knocking to occur.

The knock phenomenon occurs not only in downsized diesel engines but also in other situations that are expected to increase thermal efficiency by further increasing the compression ratio or pressure. (Xu et al., 2022). Based on this description, it can be concluded that the process of smooth operation of the ship depends heavily on the ship's machinery, if the main engine experiences detonation, then the engine must be repaired immediately; the repair process will interfere with the operation of the ship that will sail. The objectives of this research are a) Identify detonation that occurs in the Main engine. b) Analyze the causes and consequences of detonation.

LITERATURE REVIEW

Parameters that must be considered in engines that experience detonation: a). The cetane value of fuel, i.e., fuel with high octane and low cetane numbers, is preferred for DF-HCCI engines or RCCI engines (Gawale & Naga., 2020). Sub-optimal fuel, poor quality/low octane fuel. b). Injectors are required to ensure that fuel injection takes place in the cylinder's hottest region and consider the form of skip combustion by varying the pilot size between cylinders and periodically over several cycles. Its combustion products can exit quickly into the main chamber to ignite the

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pre-mixed gas-air mixture. (Karim, 2015: 128). c). Injection timing Mixtures, loads, and injection timing are optimized through compression ignition engines' performance, combustion, and emission characteristics (Jayaraman et al., 2023). If the injection timing is too early, the result is diesel knock, while too far will lower the maximum pressure in the cylinder, which causes reduced engine power and increased fuel consumption, making it more wasteful. d). Increased compression on combustion will result in the onset of combustion faster than the combustion timing, resulting in detonation in diesel engines. Compression ignition (CI) engines use compressed air to initiate combustion, described by the fuel equivalence ratio. (Windarto et al., 2023). e). Carbon will become a heat source so that when the fuel and air are compressed, it will burn faster. Soot formation occurs at high temperatures in the cylinder, particularly in the combustion chamber zone with a fuel-rich mixture, i.e., oxygen-deficient conditions. (Agarwal et al., 2019).

RESEARCH METHOD

This research uses qualitative research methods. The ability to collect true and accurate data, information, or truth is another expectation related to the presence of a method in research. Qualitative methods are used when researchers want to understand the condition of the object under study in more depth and are difficult to express quantitatively. (Sugiyono, 2021:254). This research was carried out for 12 months and one day on the MV. Tanto Hemat during the sea work program, which started on August 15, 2021, to August 16, 2022, on MV. Tanto Hemat with a container ship type ship owned by the Tanto Intim Line company. Research was also carried out at PIP Semarang in the VII and VII semesters.

This data collection technique uses three different methods, namely interviews, observation. documentation. This research uses Strength, Weakness, Opportunity, and Threat (SWOT) indicators to compare external opportunities and threats with internal strengths and weaknesses. (Rangkuti, 2013: 19). Observation of researchers can follow and observe the object to be studied and how to handle it. Documentation is proven in the documents included in this study, such as manual books, engine spare parts, engine month reports, and photos of work on the ship.

Tabel 1. Internal and External Factor

1	**STRENGTH**
	Valve leakage at cylinder head
	Injector pressure 300 kg/cm^2
	Injection timing
	Carbon buildup in the combustion chamber
2	**WEAKNESS**
	Piston ring damage
	RH injector that is too long
	Poor fuel quality
	Setting second timing of high-pressure fuel pump
1	**Opportunities**
	The knowledge provided by the previous engineer
	Improvised injector adjustment from superintendent
	Assistance from ground technicians in analyzing main engine performance
	Selection of competent machinists from the company office

2	**Threats**
	Inadequate spare part supply
	DPA communication that is not harmonious
	Spare part recondition
	Spare parts that are not in accordance with standard provisions

Interviews were conducted on board with the aim of obtaining information from respondents, namely Machinist 1 and KKM on the topic of detonation on the main engine. The following is a table of interviews from the interviewees:

Table 2. Table of Interviews

Indicator	Source Chief Engineer	Source engineer 1
Constraints	• Improper timing of fuel injected into the combustion chamber • Intake and exhaust valve leaks, as we found yesterday during the overhaul	• Injector pressure less than 300 kg/cm2 • Carbon buildup in the combustion chamber
Efforts	• Fuel timing check • Replacement of cylinder head with new seating valve and valve or reconditioning	• Check combustion chamber condition and perform carbon removal • Injector maintenance and adjust injector pressure to 300 kg/cm2

Data validity testing using the triangulation test can be taken from various sources, and different points of view can confirm and validate research findings, making the results more reliable and relevant.

FINDINGS AND DISCUSSION

It is necessary to know that detonation occurs when the pressure and temperature inside the cylinder increase rapidly, and the air fuel mixture burns itself before the time desired by the engine. The different increasing effect of the flame front on the high-pressure and low-pressure regions results in an increasing pressure difference, eventually forming a knock. (Wu et al., 2023). Ignition delay is fuel and air combustion after the specified timing. The diesel engine timing gear system is one of the most important drive systems, which controls the working of the valve mechanism and fuel system to ensure proper operation of the diesel engine. (Yuan et al., 2020). When the combustion timing is not appropriate, there will be a loud knocking sound on the main engine in sequence, which can endanger the Main Engine.

The fuel pump is a component in the Main Engine to deliver fuel into the cylinder through

the injector. Using high-viscosity biodiesel results in poor fuel injection pump performance, which causes a decrease in diesel engine performance (Anis et al., 2019). Simultaneously, faster spray penetration can contribute to air utilization and improve combustion speed under high load conditions (Zhai et al., 2021). The injector pressure in the Main Engine on the research vessel is 300 kg/cm2 in a single spray, improper fuel characteristics directly translate into the efficiency and durability of engine components. Contaminants cause an increase in the intensity of corrosive and abrasive wear, and incorrect self-ignition properties result in chronic combustion or no combustion in the cylinder. (Chybowski et al., 2023). Injectors that do not function properly will use more fuel, and the combustion results will be less than optimal. Research shows that proper injection timing improves engine combustion and fuel economy (Li et al., 2022). The fuel injection process in modern diesel engines is based on high pressure and small nozzle hole diameter to improve spray atomization. However, these conditions cause cavitation in the fuel injector and nozzle (Balz et al., 2020). Each injector on the Main Engine has working hours that must be checked, which is about 1000 hours.

The cycle-to-cycle amount of fuel injection increases exhaust emissions and carbon deposits (Wei et al., 2022). Carbon in the cylinder will also affect the detonation anomalies in Main Engine combustion. The intake air will be very important as an air supplier to the main engine so that the air quality must always be maintained; if the exhaust gas from combustion escapes to the scaving chamber, of course, the temperature of the rinse air will rise, and it will reduce the density between particles or the density of the rinse air decreases (density). The increase in intake air temperature causes a proportional increase in temperature pressure in the cylinder (Mansor et al., 2021). Flashpoint is an important fuel criterion because it promotes safe storage and transportation conditions and affects process operating temperatures (Huo et al., 2022).

The temperature in the combustion chamber must be maintained if it is too cold; temperatures that are too hot are also not allowed because the fuel will burn first because the temperature in the combustion chamber is too hot before the fuel and air are compressed during the compression process the fuel has burned because the flash point in the fuel is sufficient for the fuel to burn. The effect of wall conditions on the spraying and ignition process differs depending on the ambient and wall temperatures (Wu et al., 2022). Physical ignition delay refers to the formation of the fuel-air mixture, and chemical ignition delay to the time required for the rapid increase in the rate of chemical reactions. (Abdullah et al., 2021). The length of this ignition delay is critical and controls the progress of the combustion process and affects most aspects of engine performance. The temperature drop inside the cylinder causes a delay in the ignition timing, which involves a delay in combustion (Tang et al., 2022). Excessively long ignition delays result in reduced torque and efficiency with increased emissions.

This study uses a ship's main engine with the brand Daihatsu Anqing 8DKM 28E, an oil-fueled diesel engine with eight in-line cylinders manufactured by Daihatsu Diesel MFG. Ltd. The ship used for research is the MV. Tanto Hemat, which is a ship from the company PT. Tanto Intim Line was completed in 2013, with DWT reaching 8180 and GT 6659. The research vessel is an Indonesian-flagged ship. The types of goods transported on research vessels are various kinds of containers with sizes 20 feet and 40 feet and have LOA reaching 119. 9 x 22 m 3480 HP (2595 KW) x 600 RPM.

Identify detonation in the Main Engine. This symptom, also known as knocking or diesel knock, occurs when diesel fuel burns too fast or too much in the engine combustion chamber. This can lead to uncontrollably high pressures and temperatures, damaging the engine. a) Ignition delay occurs in the Main Engine, Ignition delay can occur due to one of them, namely low injector pressure or less than 300 kg / cm2. So that the flame propagation becomes longer and detonation will occur

in the Main Engine; b) the occurrence of pre-ignition in the Main Engine, Pre-ignition occurs and hot spots in the combustion chamber, carbon scale deposits, low-quality fuel, or the use of fuel with too low an octane value.

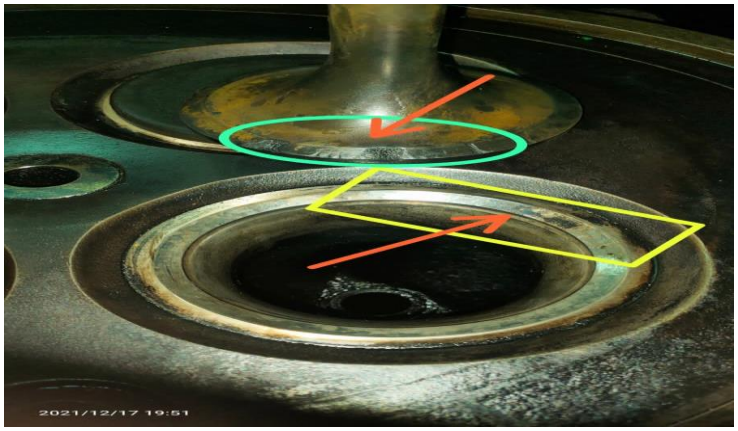

Figure 1. Damage to one of the seating and exhaust valves of cylinder 6

Figure 2. Inaccurate mark on the main engine timing gear

Causes and consequences of detonation: a). poor fuel quality, such as water or impurities, can interfere with normal combustion in diesel engines and too much injected fuel. b). high pressure and temperature inside the engine combustion chamber can be caused by too early, too much, or too hot fuel injection. c). lack of sufficient air circulation inside the engine combustion chamber can cause unbalanced temperature and pressure; d). poor oil quality or overheated oil, which can result in increased friction and pressure on the engine, burned oil will produce carbon or scale in the combustion chamber and not only incomplete combustion such as unburned residual combustion fuel will also leave carbon in the combustion chamber, e). damage to the fuel injection system, such as blockages or leaks, which can interfere with normal combustion in diesel engines. At the time of injection, the fuel that comes out is not completely in the form of mist but still in liquid form because the nozzle is clogged from a leak from the injector, f). timing of improper combustion resulting in premature ignition, which causes a knocking sound called detonation or knocking.

The consequences of detonation will also be detrimental to the engine, as follows: a). detonation will cause an increase in fuel consumption used because the power released when detonation occurs will be reduced so that more fuel supply is needed to meet the required power; b). performance in the main engine will be reduced because the power generated is not maximized,

as evidenced by Pmax testing, c). Oil from the sump tank will quickly decrease due to wear from the piston ring; d). damage from engine spare parts and will shorten the running hours of each engine component, and replacing spare parts needs a lot of money, e). carbon buildup in the combustion chamber which will increase the temperature in the combustion chamber and increase the temperature in the main engine.

Previous research on detonation was used to strengthen the existing data in this study according to Rosid's (2017) research title "Analysis of the Occurrence of Knocking on Diesel Generators" with the Fault Tree Analysis method, which discusses detonation concludes the main cause of detonation in the study is low compression and ignition delay that occurs in diesel engines, these factors are also experienced in this study so that the factors in this study are strengthened by the presence of the same factors about the cause of detonation, namely low compression and ignition delay.

In research according to Suratman (2019) entitled "Causes of Knocking Valve in Diesel Engines" using USG (Urgency, Seriousness, Growth), the occurrence of knocking valve in diesel engines is caused by camshaft installation errors or timing of combustion, ignition delay process, fuel quality. The three descriptions are the top three USG table ranks or the study's most important factors. The top three descriptions of the factors causing detonation will strengthen the data on the SWOT variable causes of detonation in this study.

CONCLUSIONS

Detonation in the main engine can be identified by 1). ignition delay that makes flame propagation longer. 2). pre-ignition, which occurs when the fuel has burned before timing. The cause and effect of diesel engine detonation is from the fire triangle factor in one of the elements is not perfect both from heat, fuel, and air, resulting in combustion faster than the timing of the diesel engine or, often referred to as detonation. The result of detonation is damage to diesel engine spare parts caused by detonation, fuel consumption will be wasteful.

REFERENCES

Abdullah, I., Khalid, A., Jaat, N., Saputra Nursal, R., Koten, H., & Karagoz, Y. (2021). A study of ignition delay, combustion process and emissions in a high ambient temperature of diesel combustion. *Fuel, 297,* 120706. https://doi.org/10.1016/j.fuel.2021.120706

Agarwal, A. K., Jiotode, Y., & Sharma, N. (2019). Endoscopic visualization of engine combustion chamber using diesoline, diesosene and mineral diesel for comparative spatial soot and temperature distributions. *Fuel, 241*, 901–913. https://doi.org/10.1016/j.fuel.2018.11.068

Anis, S., & Budiandono, G. N. (2019). Investigation of the effects of preheating temperature of biodiesel-diesel fuel blends on spray characteristics and injection pump performances. *Renewable Energy, 140,* 274–280. https://doi.org/10.1016/j.renene.2019.03.062

Balz, R., von Rotz, B., & Sedarsky, D. (2020). In-nozzle flow and spray characteristics of large two-stroke marine diesel fuel injectors. *Applied Thermal Engineering, 180,* 115809. https://doi.org/10.1016/j.applthermaleng.2020.115809

Chybowski, L., Myśków, J., & Kowalak, P. (2023). Analysis of fuel properties in the context of the causes of three marine auxiliary engines failure – A case study. *Engineering Failure Analysis, 150.* https://doi.org/10.1016/j.engfailanal.2023.107362

Gawale, G. R., & Naga Srinivasulu, G. (2020). Experimental investigation of propanol dual fuel HCCI engine performance: Optimization of propanol mass flow rate, impact of butanol blends (B10/B20/B30) as fuel substitute for diesel. *Fuel, 279,* 118535. https://doi.org/10.1016/j.fuel.2020.118535

Huo, X., Lu, Q., & Wang, J. (2022). Liaw-UNIFAC flash point model for alcohols-kerosene/diesel fuel

blends using average fuel structure. *Process Safety and Environmental Protection, 160*, 400–410. https://doi.org/10.1016/j.psep.2022.02.027

Jayaraman, J., Arunkumar, T., Senthil Kumar, P., Mariadhas, A., Appavu, P., & Rangasamy, G. (2023). Performance analysis on a compression ignition engine fueled with algae, rice bran methyl esters, and their diesel blends at optimized blend proportion, injection timing and load. *Fuel, 344,* 128024. https://doi.org/10.1016/j.fuel.2023.128024

Karim.A. G. (2015). *Dual Fuel Diesel Engine*. New York: Taylor & Francis

Li, J., Zhang, Z., Ye, Y., Li, W., Yuan, T., Wang, H., Li, Y., Tan, D., & Zhang, C. (2022). Effects of different injection timing on the performance, combustion and emission characteristics of diesel/ethanol/n-butanol blended diesel engine based on multi-objective optimization theory. *Energy, 260*, 125056. https://doi.org/10.1016/j.energy.2022.125056

Mansor, M. R. A., Mohamad, T. I., & Sabah, O. (2021). Numerical investigation on combustion and emissions in a direct injection compression ignition engine fuelled with various hydrogen–methane–diesel blends at different intake air temperatures. *Energy Reports, 7*, 403–421. https://doi.org/10.1016/j.egyr.2021.07.110

Rosid, K. (2021). *Analisis Penyebab Terjadinya Knocking Valve Pada Mesin Diesel Generator DI MV. Kartini Baruna*. Repository.pip-semarang.ac.id

Rangkuti, F. (2013). *Teknik Membedah Kasus Bisnis Analisis SWOT Cara. Perhitungan Bobot, Rating, dan OCAI*. Jakarta: PT. Gramedia Pustaka Utama

Sugiyono. (2021). *Metode Penelitian Tindakan Komprehensif.* Bandung: Alfabeta

Suratman, S. (2019). *Analisis Penyebab Terjadinya Knocking Pada Mesin Diesel Generator di MT. Anggraini Excellent.* Repository.pip-semarang.ac.id

Tang, X., Wang, P., Zhang, Z., Zhang, F., Shi, L., & Deng, K. (2022). Effects of high-pressure and donor-cylinder exhaust gas recirculation on fuel economy and emissions of marine diesel engines. *Fuel, 309*, 122226. https://doi.org/10.1016/j.fuel.2021.122226

Wei, Y., Zhang, H., Fan, L., Gu, Y., Leng, X., Deng, Y., & He, Z. (2022). Experimental study into the effects of stability between multiple injections on the internal flow and near field spray dynamics of a diesel nozzle. *Energy, 248*, 123490. https://doi.org/10.1016/j.energy.2022.123490

Windarto, C., Setiawan, A., Ho, N., & Duy, X. (2023). ScienceDirect Investigation of propane direct injection performance in a rapid compression and expansion machine: Pathways to diesel marine engine efficiency parity with spark discharge duration strategies. *International Journal of Hydrogen Energy*. https://doi.org/10.1016/j.ijhydene.2023.05.131

Wu, H., Dong, X., Shi, Z., Li, H., Cao, W., Zhang, L., Bo, Y., & Li, X. (2022). Effect of injection timing on knock combustion and pollutant emission of heavy-duty diesel engines at low temperatures. *Chemosphere, 305,* 135519. https://doi.org/10.1016/j.chemosphere.2022.135519

Wu, Y., Liu, L., Liu, B., Cao, E., & Xiong, Q. (2023). Investigation of rapid flame front controlled knock combustion and its suppression in natural gas dual-fuel marine engine. *Energy, 279*(15 September 2023), 128078. https://doi.org/10.1016/j.energy.2023.128078

Xu, H., Ni, X., Su, X., Weng, C., & Yao, C. (2022). The effect of ignition intensity and in-cylinder pressure on the knock intensity and detonation formation in internal combustion engines. *Applied Thermal Engineering, 200,* 117690. https://doi.org/10.1016/j.applthermaleng.2021.117690

Yuan, Y., Wang, Z., Wang, D., Dong, L., Li, W., & Guo, Y. (2020). Failure investigation of a marine diesel engine timing gear. *Engineering Failure Analysis, 107,* 104203. https://doi.org/10.1016/j.engfailanal.2019.104203

Zhai, C., Jin, Y., Wu, Q., Nishida, K., & Ogata, Y. (2021). Diesel spray and combustion of multi-hole

injectors with micro-hole under ultra-high injection pressure – Combustion characteristics. *Fuel, 300,* 120949. https://doi.org/10.1016/j.fuel.2021.120949