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The effect of additive addition to fuel with variations in preheating and water coolant on multi-cylinder diesel engine performance

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Abstract

Diesel engines are essential for transporting heavy loads, requiring significant engine power. This study aims to evaluate the effect of adding PTT (diesel fuel conditioner) additives to Dexlite fuel, focusing on mixtures of D0, D1, and D2. Additionally, variations in fuel pre-heating and engine cooling system fluids are examined. This research employs an experimental approach with descriptive analysis. The findings indicate that the optimal torque occurs with the D2 mixture, achieving 136.57 N·m at 2267 rpm with standard coolant, 152.03 N·m at 2100 rpm with a 50%:50% fluid ratio, and 160.70 N·m at 2033 rpm with a 30%:70% fluid ratio, all without pre-heating. The optimal power values for the D2 mixture are 74.60 HP at 4600 rpm with standard fluid, 75.23 HP at 4100 rpm with a 50%:50% fluid ratio, and 78.03 HP at 4000 rpm with a 30%:70% fluid ratio, also without pre-heating. The average results show that the D1 and D2 mixtures improve torque values by 0.77% and 4.75%, respectively, and enhance power by 0.19% and 1.53% compared to pure Dexlite. In contrast, pre-heating at 50°C, 60°C, and 70°C resulted in a decrease in torque of 1.00%, 2.26%, and 3.62%, respectively, and a reduction in power of 0.56%, 2.29%, and 4.79% compared to normal temperature conditions.

1. INTRODUCTION

In 2022, the human population in Indonesia reached 278 million (Central Bureau of Statistics, 2023). Consequently, the number of vehicles in the country continues to grow each year. Diesel engines are commonly used in transportation, construction machinery, energy generation, and military applications (Iskandar et al., 2020; Naryanto et al., 2023). The Central Bureau of Statistics of Indonesia reported that in 2021, a total of 16,950,275 car-type vehicles were produced (Central Bureau of Statistics, 2023). Data from the Association of Indonesian Automotive Industries (GAIKINDO) indicates that in 2020, Toyota sold 12,557 units of the Kijang Innova and Fortuner models. In the same year, Mitsubishi Motors sold 3,410 units of the Pajero model, and Isuzu sold 1,501 units of the Panther model (Wibowo, 2020). Diesel engines are known for their low fuel consumption, longevity, and high thermal efficiency (Iskandar et al., 2024; Zhang, 2023). Based on this data, it's clear that Indonesians have a strong interest in diesel-powered cars, including private vehicles, public transportation, and commercial vehicles.

To effectively meet the community's transportation needs, particularly for the heavy loads carried by diesel vehicles, significant improvements in diesel engine performance are essential. A key strategy for enhancing this performance is to boost the quality of the fuel, specifically by increasing its cetane number. A higher cetane number not only makes diesel fuel easier to ignite but also significantly reduces the combustion delay time, leading to better engine efficiency (Haikal, 2022). By incorporating specially formulated additives, we can elevate the cetane number of diesel fuel, which directly translates to enhanced engine power and performance (Cahyanti, 2023). These additives, available in either liquid or pill form, are designed to maximize the calorific value of combustion, making diesel engines more effective and reliable (Ulana & Subroto, 2023). Embracing these innovations is crucial for the future of diesel engine performance.

The cetane number, along with density, viscosity, calorific value, and surface tension, plays a crucial role in optimizing diesel engine performance. Research by Kodate et al. (2021) demonstrates that fuels with high viscosity are challenging to burn, leading to inefficient combustion due to fogging during fuel injection (Anis & Budiandono, 2019). When viscosity levels exceed 5 mm^2/s, fuel fogging further complicates evaporation in the combustion process (Widjanarko et al., 2021).

To tackle this challenge, preheating the fuel before injection into the combustion chamber is highly effective. Heating the fuel to 50°C reduces both viscosity and density, resulting in a noticeable increase in torque and power. However, it's important to note that heating above 60°C can reduce average torque and power outputs (Maulana et al., 2023). Therefore, careful control of fuel temperature is vital for achieving optimal engine performance.

The combustion of diesel engines generates substantial heat, which can significantly affect engine components and overall performance. To mitigate the risk of excessive heat buildup or overheating, an efficient cooling system is essential for regulating temperature effectively (Mufti & Wahid, 2020). The operating temperature of a diesel engine is critical; it directly influences performance and longevity (Hossain et al., 2017). As highlighted by Suparno et al. (2020), choosing a cost-effective and high-performing coolant is paramount. Ethylene glycol, when mixed with water, proves to be an exceptional option due to its superior ability to absorb and stabilize engine temperatures (Fauzi et al., 2020).

Recognizing the significant impact of coolant on engine performance, we conducted tests with three varieties of coolant to pinpoint those that offer optimal thermal efficiency and enhanced performance. Moreover, this study will delve into how variations in the cetane number of fuel—when combined with additives and pre-heating methods—affect the operation of multi-cylinder diesel engines. By examining these different factors, we aim to unlock greater efficiency in diesel engines, ensuring they perform at their best while extending their life.

2. RESEARCH METHODS

This study uses a quantitative approach design with experimental methods and data analysis techniques using descriptive analysis.

This research initiated with the precise mixing of Prestone concentrated water coolant and distilled water (aquadest) in two optimal ratios: 50% coolant to 50% water and 30% coolant to 70% water. In addition, we intelligently combined dexlite fuel with PTT (diesel fuel conditioner) additives, adhering to the recommended application—3 ml per liter for a standard dose and 6 ml per liter for an enhanced double test dose of dexlite. After meticulously preparing the fuel and water coolant, we stored the fuel in a heater tank where it was heated to specific temperature variations for testing. Once the fuel reached its ideal temperature, it flowed through a filter to the injection pump and was precisely injected into the combustion chamber. Any surplus fuel efficiently returned to the heater tank through the return pipe, ensuring a seamless and effective system. This approach not only enhances performance but also maximizes fuel efficiency, making it a compelling choice for optimal results.

The flow of this research is depicted in Figure 1.

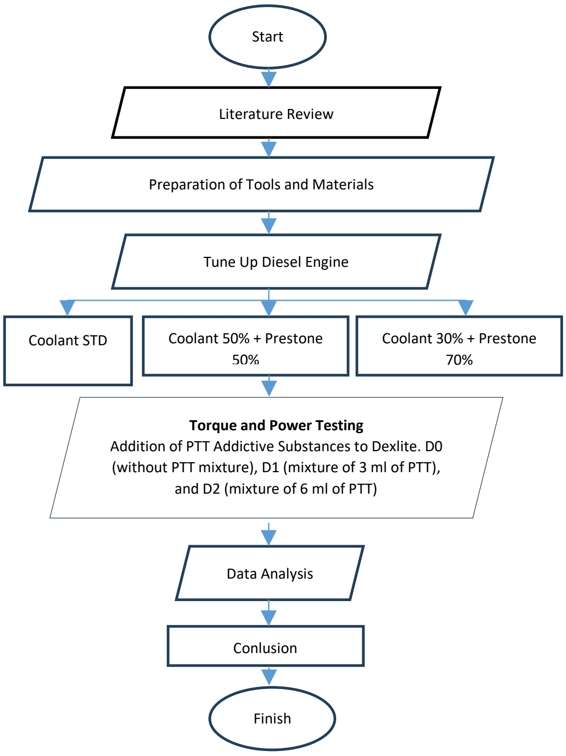

Figure 1. Research Flow Diagram

In this study, the independent variables investigated include variations in fuel mixtures: D0 (without PTT mixture), D1 (a mixture containing 3 ml of PTT), and D2 (a mixture containing 6 ml of PTT). Additionally, variations in fuel heating are tested at temperatures of 50°C, 60°C, and 70°C. The study also examines different types of water coolants, including Isuzu factory standard coolant (STD), Prestone 50%:50%, and Prestone 30%:70%.

The dependent variables in this study focus on engine performance, specifically torque and power. Control variables include fuel temperatures ranging from 50°C to 70°C, an engine working temperature of 70°C to 80°C, the addition of 3 ml and 6 ml of additives, and the use of 100% dexlite fuel (Pure CN 51).

After testing the engine performance and collecting data on torque and power values, data analysis was conducted using descriptive techniques. Conclusions were drawn by calculating the average of the lowest and highest values for each test result and comparing the data accordingly. This method provides a comprehensive overview and explanation of the performance testing results, specifically the torque and power outcomes of the diesel engines. The quantitative data obtained from the engine

3. RESULTS AND DISCUSSION

3.1. Engine Torque Test Results

The results of the engine performance test are in the form of torque values in Figure 2.

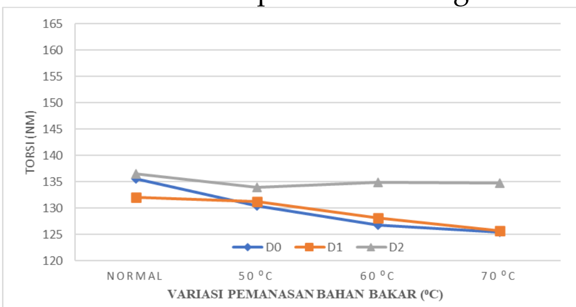

Figure 2. Effect of Pre-Heating and Addition of PTT Additives to Diesel Fuel Using STD Water Coolant on Maximum Torque Value

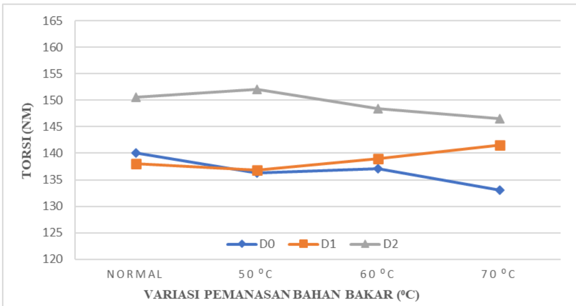

Figure 3. Effect of Pre-Heating and Addition of PTT Additives to Diesel Fuel Using Prestone Water Coolant 50%:50% on Maximum Torque Value

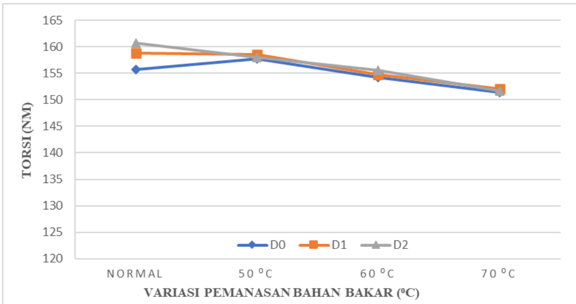

Figure 4. Effect of Pre-Heating and Addition of PTT Additives to Diesel Fuel Using Prestone Water Coolant

The highest torque value obtained from the engine performance tests was recorded in the D2 mixture at normal temperature, with values of 136.57 Nm, 152.03 Nm, and 160.70 Nm for each variation of water coolant used. Conversely, the lowest torque value was found in the D0 mixture at a temperature of 70 °C, yielding values of 125.43 Nm, 133.10 Nm, and 151.33 Nm across the coolant variations. The average increase in torque was 0.77% and 4.75%, indicating that the use of the PTT additive mixture in Dexlite fuel significantly enhances torque compared to pure Dexlite fuel. According to Cahyanti (2023), the addition of additives to diesel fuel increases the cetane number, which can further improve engine performance. The torque values generated from the fuel heating process showed a decreasing trend with rising fuel temperature. As noted by Maulana (2023), excessively low viscosity and fuel density values can adversely affect engine performance. This decrease in torque appears to result from changes in the fuel's viscosity due to excessive heating, which makes the fuel burn prematurely and may lead to engine knocking.

The variations in water coolant used during diesel engine performance testing are based on the torque values obtained from the D2 mixture. The torque value includes the best result from each test variation, as illustrated in Figure 5.

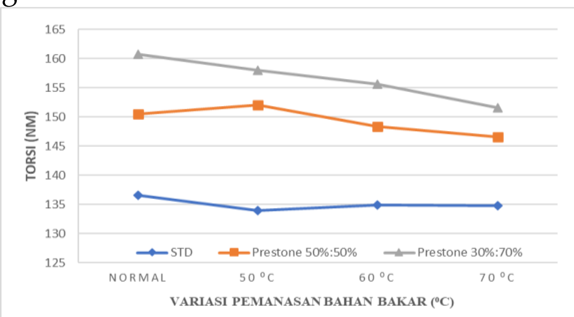

Figure 5. Effect of Water Coolant Use on Engine Torque Value

Figure 5 demonstrates that the type of water coolant used significantly influences engine performance, particularly by increasing engine torque values. Among the three types of water coolant tested, the STD water coolant produced the highest torque value of 136.57 Nm. The Prestone 50%: 50% mixture yielded a maximum torque of 152.03 Nm, while the Prestone 30%: 70% mixture achieved the highest torque value of 160.70 Nm. This results in an average torque increase of 11.33% and 17.67%, respectively, when compared to the torque produced by the STD water coolant. To address excessive heat buildup, which can reduce engine performance, heat control is implemented using a cooling system (Mufti & Wahid, 2020). This confirms that using an effective heat absorption medium in the engine can help manage overheating and maintain an optimal engine temperature, thus enhancing overall engine performance and torque outputs.

3.2. Engine Power Test Results

The results of the engine performance test are in the form of power values in Figure 6.

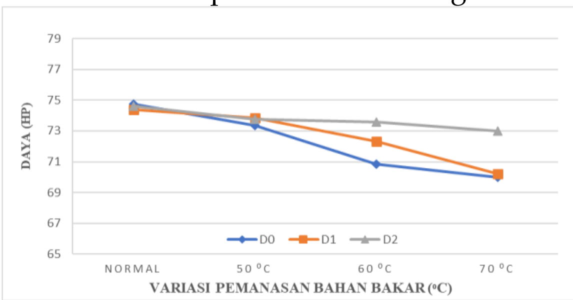

Figure 6. Effect of Pre-Heating and Addition of PTT Additives to Diesel Fuel Using STD Water Coolant on Maximum Power Value

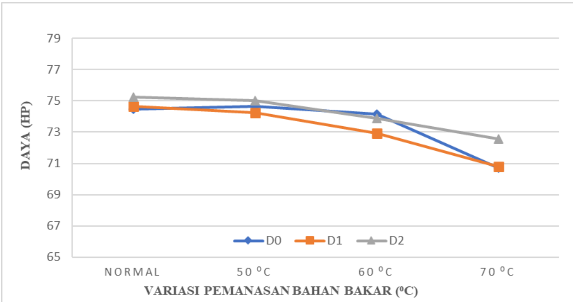

Figure 7. Effect of Pre-Heating and Addition of PTT Additives to Diesel Fuel Using Prestone Water Coolant 50%:50% on Maximum Power Value

Based on the analysis of maximum power gain with variations in fuel heating, an increase in power is observed with each variation of fuel preheating using different coolants. The highest increase in power occurs at normal temperature, indicating that fuel heating significantly affects the viscosity of the fuel. This finding aligns with Maulana's research (2023), which states that higher fuel preheating before injection into the combustion chamber tends to reduce the power output in a diesel engine.

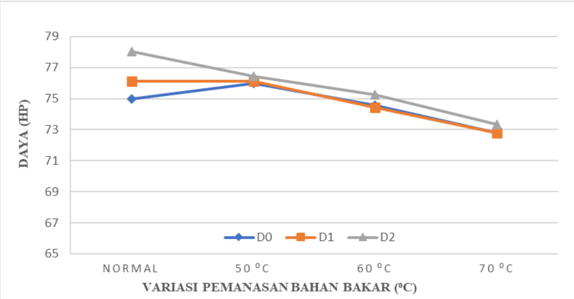

Figure 8. Effect of Pre-Heating and Addition of PTT Additives to Diesel Fuel Using Prestone Water Coolant 30%:70% on Maximum Power Value

Based on the analysis of maximum power gain with variations in fuel heating, an increase in power is observed with each variation of fuel preheating using different coolants. The highest increase in power occurs at normal temperature, indicating that fuel heating significantly affects the viscosity of the fuel. This finding aligns with Maulana's research (2023), which states that higher fuel preheating before injection into the combustion chamber tends to reduce the power output in a diesel engine.

The optimal power value obtained during engine performance testing was 78.03 HP using D2 fuel with a normal temperature variation of 30% pristine water coolant, while the lowest power value of 70.00 HP was recorded with D0 fuel at a heating temperature of 70 °C using a standard water coolant. The average power increase based on the mixture of D1 and D2 fuels was 0.19% and 1.53%, respectively. This indicates that the use of the PTT additive mixture in dexlite fuel significantly enhances the power output compared to pure dexlite fuel.

During the diesel engine performance testing, variations in water coolant were based on the power values obtained from the D2 mixture, as it produced the best power output in each test variation, as illustrated in Figure 9.

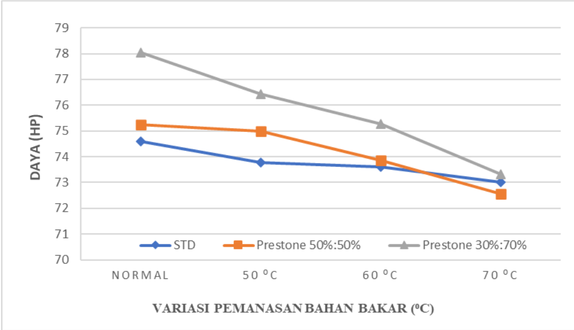

Figure 9. Effect of Water Coolant Use on Engine Power Value

Figure 9 illustrates the impact of different water coolants on engine power output. It is evident that using water coolant significantly enhances engine performance by increasing power values. Among the three types of water coolants tested, the STD water coolant achieved a maximum power output of 74.60 HP. The 50% Prestone coolant reached a higher power value of 75.43 HP, while the 30% Prestone coolant produced the highest output at 78.03 HP. This represents an average power increase of 0.67% and 4.42% compared to the power produced by the STD water coolant. These results demonstrate that a cooling system utilizing water coolant, tailored to the engine's characteristics, can effectively improve engine performance, particularly in terms of power output.

4. CONCLUSION

This study demonstrates that adding PTT (Diesel Fuel Conditioner) additives to diesel fuel significantly enhances the performance of the Isuzu Panther multi-cylinder diesel engine, improving both torque and power. The optimal results are achieved with a D2 fuel mixture (6 ml/liter), which yields a torque of 160.70 Nm and a power output of 78.03 HP, reflecting increases of 4.75% and 1.53%, respectively. In contrast, pre-heating the fuel above 50°C leads to reduced performance due to a decrease in fuel viscosity. Furthermore, utilizing a coolant mixture composed of 30% Prestone and 70% distilled water results in an increase of 17.67% in torque and 4.42% in power. Therefore, for optimal performance, it is recommended to use PTT additives mixed with D2, limit pre-heating to a maximum of 50°C, and maintain a coolant ratio of 30% Prestone to 70% distilled water. For future research, it is suggested that laboratory testing on the characteristics of blended PTT additive fuel and exhaust emissions be conducted to evaluate pollution levels and ensure compliance with relevant emission standards.

5. DECLARATION/STATEMENT

5.1. Author Contribution

All authors collaborate throughout the writing process until publication.

5.2. Conflict of Interest

All the research results were consistent and showed no conflicts.

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