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Modification Monitoring of Combustion Chamber Temperature and Pressure on Diesel Engines

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Abstract

Along with the development of technology in the industry, especially automotive, professional workers who are reliable and master their fields in theory and practice are expected. Ideally, educational institutions such as polytechnics should provide adequate equipment and facilities to achieve learning objectives. A critical process in the combustion engine system is where a cycle of pressure and temperature changes at each piston stroke. Unfortunately, many students' understanding of the diesel engine cycle system still needs to be improved, even though the diesel engine cycle had been discussed in the engine system course or thermodynamics. Therefore, this study was intended to modify the Diesel Engine in the heavy equipment workshop to be used as a learning media for the combustion engine and thermodynamic, especially the diesel cycle. This research started with identifying and preparing to identify and to prepare equipment and materials, installing pressure and temperature sensors, controller installation, calibration, and final testing. The test results show the correspondence between the theoretical and experimental cycles, although a few typical differences usually occur between theoretical and practical in the field.

Keywords: Diesel Engine, Modification, Temperature, Pressure, Monitoring.

INTRODUCTION

Theoretically, the diesel cycle can be described with P-V and T-S diagrams, where the Pressure (P) and Volume (V) are also the Temperature (T) and Entropy (S) that occur in the combustion chamber. However, the parameter conditions in the field were found to be not ideal, resulting in the temperature and pressure readings being very far from their theoretical values. The value read on the gauge does not describe the actual condition of the combustion chamber temperature. This value is the cooling water temperature data. This condition is challenging for diesel engine users to clearly describe the relationship between P-V and T-S diagrams with actual combustion chamber conditions. As a result, many users do not understand the relationship between temperature and pressure in natural conditions and are still misrepresented compared to existing theories.

Diesel engines are used as a power source to help ease human tasks such as motors, generators, land and sea transportation (Smith et al., 2016). The advantages of diesel are high thermal efficiency, low fuel consumption, and good durability compared to gasoline engines (Purwanti et al., 2019). When fresh air enters the combustion chamber, the diesel engine combustion occurs at the ignition compression engine. Diesel fuel is injected into the combustion chamber near the end of the compression stroke, resulting in automatic ignition followed by an increase in pressure and temperature resulting from the compressed air (Cahyono et al., 2020). Diesel engines are divided into two categories based on the combustion system, namely indirect injection diesel engines and direct injection diesel engines according to performance and emission tests (Putrasari et al., 2013).

Several modifications to the diesel engine have also been carried out, and their performance tested. The energy content of gas fuel mixed with sprayed diesel is varied in the amount of 0%, 15%, 40%, and 75% of the total energy content of the fuel. researchers (Karagöz et al., 2016). Meanwhile, several injection cases have been explored for the diesel engine concerned and have been found to reduce unburned Hydrocarbons and Carbon monoxide with minimal NOx penalty (Sharma et al., 2010). However, this research still uses pressure and temperature sensors located far from the combustion chamber (still original). Indirect injection diesel engine compression ignition technology operates using fresh compressed air at the tip of the combustion chamber. The vortex effect on the pre-chamber or swirl chamber, high pressure, and temperature are the main factors in this system (Yuan et al., 2014). The disadvantage of the indirect injection system is that the combustion takes a longer duration because the flame propagation in the combustion chamber causes higher heat loss through the combustion wall. Lower compression ratio and longer combustion process in indirect injection systems lead to lower thermal efficiency than direct injection systems.

The effect of temperature distribution in the injected fuel jet on the emission of excess air coefficient is considered to ensure the reduction of solid particles in diesel engine exhaust gases by the combustion process (Barinov, 2020). Therefore the advantage of the indirect injection system is that it is more adaptive, especially if the fuel quality is low and the noise level caused by the system is relatively low.

Based on a review of the advantages and disadvantages of the indirect injection system, research was carried out by modifying the Perkin P13.5-4 engine located in a heavy equipment workshop to be able to monitor its combustion temperature directly and pressure so that it can be used as a learning medium for internal combustion engines and theory, thermodynamics, especially the diesel cycle.

METHOD

This research was conducted using an experimental method. The engine used in this study is a Perkin P135-4 diesel engine with three cylinders with a power of 13.5 hp and is mounted on a generator set, as shown in Figure 1.

Perkin P135-4 diesel engine combustion chamber is shown in Figure 2. The pressure and temperature sensor installation are carried out by utilizing the existing heating plug. The heating plug is perforated according to the size of the sensor tip. The research stages are described in the flowchart in Figure 3. The results of temperature and pressure testing, if appropriate, will be analyzed. If not appropriate, they will be repaired and then retested. The fuel injection parameters are changed to analyze the effect on the acceleration signal of the block mounted in a vertical and horizontal orientation to extract the features of the combustion process (Narayan et al., 2019).

Combustion occurs when the fuel sprayed meets air and sufficient heat, compressed as the piston moves up (Mintz et al., 2014). Fuel combustion in an explosion will sudden increase heat and high pressure in the combustion chamber. This pressure pushes the piston down, which continues with the rotating crankshaft (Siczek, 2016). This pressure pushes the piston down, which continues with the rotating crankshaft. This pressure pushes the piston down, which continues with the rotating crankshaft. With the movement of the piston to get one process cycle, the internal combustion engine is divided into two types: diesel engine (4 strokes) (Wang et al., 2020). The number of jobs can be calculated according to equation 1.

$$W_{0-1} = P_0 (V_1 - V_0) \quad (1)$$

Where P0 is the pressure at point 0, in kPa, V1 is the volume at point 1, in m^3, V0 is the volume at point 0, in m^3, W0-1 is the work done from point Volume 0 to Volume 1, in kJ.

In the intake stroke, the piston moves from the Top Death Center (TDC) to the Bottom Death Center (BDC), the intake valve opens, and the exhaust valve closes so that the pressure inside the cylinder becomes lower than outside. Pressure (vacuum) and air can be sucked naturally into the cylinder. In the compression stroke, the piston moves from BDC to TDC. At that time, the intake valve and exhaust valve are both closed so that the air in the cylinder is compressed and causes high heat and pressure. At the end of this compression stroke, the fuel is sprayed at very high pressure through a tiny opening, resulting in combustion (in the form of an explosion) (Park et al., 2016). A combustion explosion at the end of the compression stroke or the beginning of the power stroke creates very high pressure. In the combustion chamber, as a result of which the piston is pushed from TDC to BDC. At the end of the power stroke, an exhaust valve opens and causes the exhaust gases to be pushed to the exhaust valve to move the piston from BDC to TDC.

The first step of the gasoline cycle begins when the piston moves from TDC to BDC where air enters through the intake valve, followed by compression, and then fuel is injected into the combustion chamber at the end of this compression stroke, causing the combustion process in the combustion chamber. The highest temperature appeared at the combustion chamber side, which occurred at the edges of the piston top face in direct contact with the hot gases in the radial. The piston deformation value is a safe margin, and the gap between the piston and the cylinder bore is in the case of engine power.

Figure 1. The engine used in this study is the Perkin P135-4 diesel engine with three cylinders with a power of 13.5 HP and is installed on the generator set.

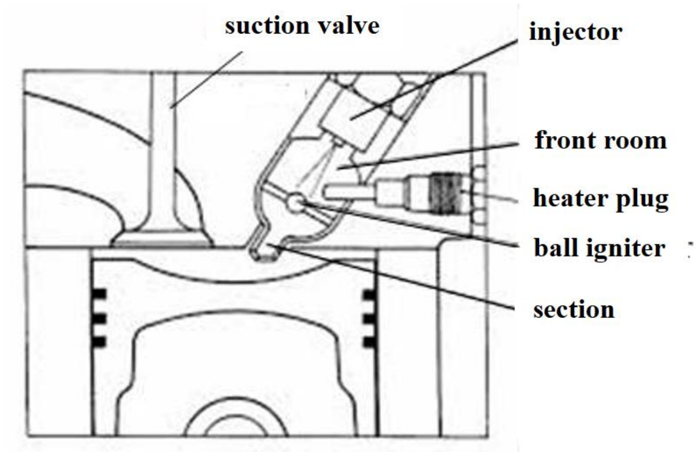

Figure 2. Perkin P135-4 diesel engine combustion chamber.

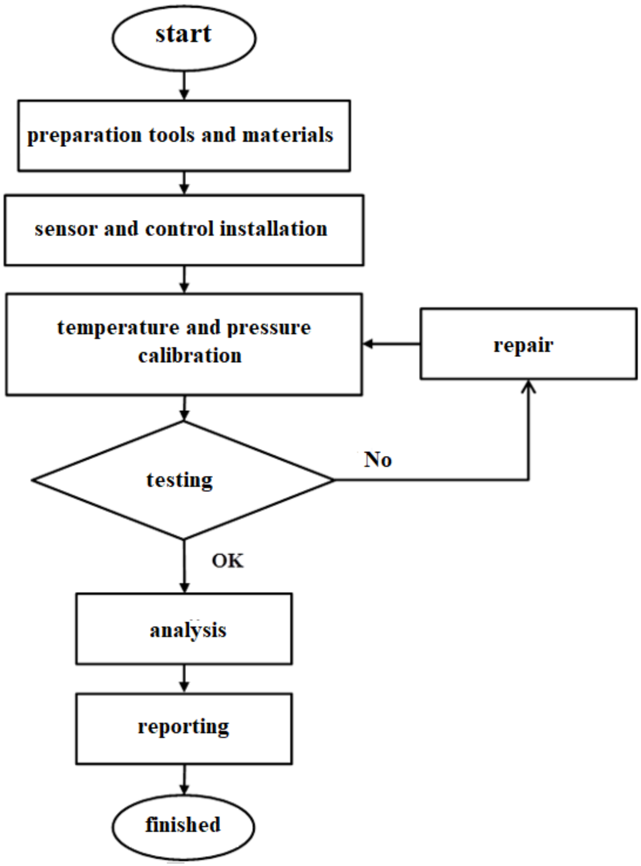

Figure 3. Experimental Flowchart measurements of pressure and temperature in the combustion chamber in one cycle of diesel cycles.

RESULT AND DISCUSSION

Achievement of the concept of monitoring, recording, processing and interpreting, on a laboratory scale, of pressure in the combustion chamber for engine spark ignition, based on electronic equipment describing operations of the internal combustion engine. In this study, pressure and temperature data obtained from sensors connected to NIDAC were taken for each time interval of 0.0025 seconds for about 11 seconds when the engine was running without load. The results of the measurement data analysis show that there are many identical cycles in the measurement time interval, where one of the cycles is presented in Figure 4. The increase/decrease in the pressure value with an increase/decrease in the combustion chamber volume due to reciprocal piston movement. T0 to T1, the temperature of the combustion chamber increases at a relatively constant pressure of about 230 Psi. This phenomenon indicates an adiabatic process in the intake stroke where the piston moves from TDC to BDC. The exhaust pressure increases the amount and temperature of the remaining gas burned, resulting in higher combustion efficiency and resulting in a longer combustion duration (Michalski et al., 2019). The fuel injection parameters are changed to analyze the effect on the acceleration signal of the block mounted in a vertical and horizontal orientation to extract the features of the combustion process (Ismail et al., 2016).

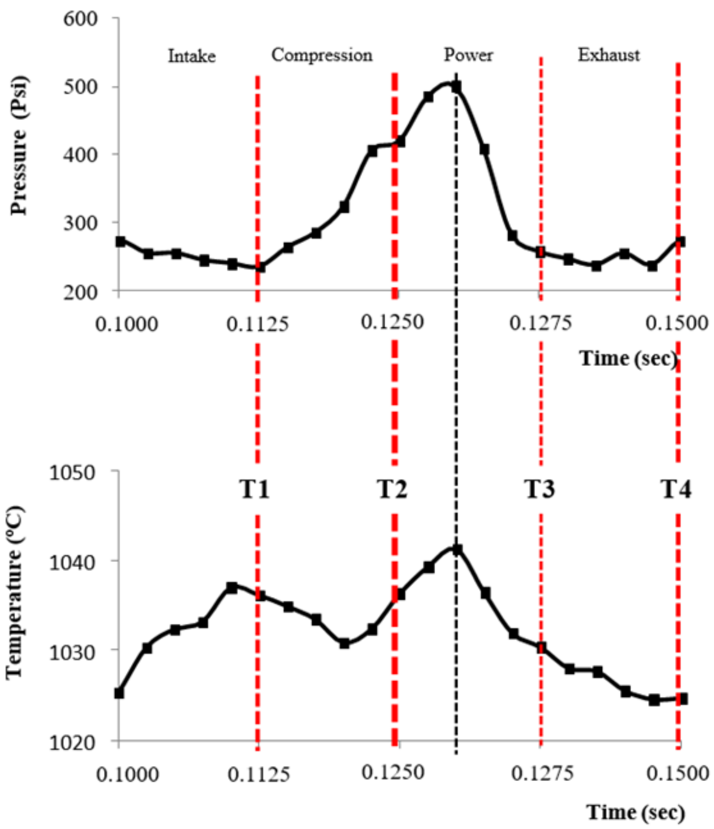

Figure 4. The results of direct measurements of pressure and temperature in the combustion chamber in one cycle of diesel cycles

b) Compression stroke/adiabatic compression (process 1 -2)

The crankshaft continues to rotate. The piston moves from TDC to BDC. Both valves are closed. The pure air was sucked and compressed in the combustion chamber. Because the compressed air temperature and pressure rises to 35 atm, the compression ratio is approximately 20:1. The formula for an ideal gas in equation 1, where P1 and P2 are the pressures at points 1 and 2 (kPa), T1 is the temperature at points 1 and 2 (K), V1 and V2 are the volumes at points 1 and 2 (m3), W1 -2 is worked in cycles 1-2 (kJ), Cp is the specific heat of the gas at constant pressure (kJ/kg.K), K is Cp/Cv, where K is the ratio of specific heat of constant pressure and specific heat of constant volume. Real-time information of the operating cycle of a dual-fuel engine, on the pressure and temperature of the combustion and cooling water pressure, should be carried out by sensors to detect
sudden variations or changes in generator mode so that failures can be identified early, adapting to changes for engine integrity (da Silva Ribeiro et al., 2018). Due to this high cylinder air pressure, the piston surface temperature increases and when the temperature reaches more than 400 to 420 °C, its role in ignition of the fuel spray becomes vital so that the surface temperature is relatively high on the diesel engine piston (Rehman, 2016)

In the combustion/expansion step at constant temperature (process 2-3), the air contained in the cylinder is pushed into the pre combustion chamber located at the top of each combustion chamber. At the end of the combustion stroke, the ignition nozzle opens and sprays a fuel mist into the pre-combustion chamber, and the heat generated by the pressure further ignites the air-fuel mixture. Changes that occur in the diesel engine or the geometry of the combustion chamber significantly affect engine performance, especially if modifications to the combustion chamber can also adapt to new types of fuel (Singh et al., 2017).

The adiabatic expansion/work stroke (process 3 -4) indicates the presence of combustion energy which expands the gas very quickly, and the piston is pushed down. The force that pushes the piston down (from TDC to BDC) is transmitted to the piston rod and crankshaft. Both valves are still closed. The piston rod transmits the downward thrust to the crankshaft to be converted into rotational motion (Viet Nguyen & Nguyen Duy 2018). This stroke stops when the exhaust valve opens a few degrees before the piston reaches BDC. On the one hand, the modification of the pressure in the combustion chamber can be analyzed depending on the crankshaft's position. Furthermore, modifying the maximum pressure in the cylinder depends on the speed (Rati et al., 2009).

Figure 5 shows the thermal efficiency of biodiesel blends with engine load compared to diesel fuel. The thermal efficiency is slightly lower for biodiesel blends than diesel fuel at all engine loads. The decrease in thermal efficiency for biodiesel blends is caused by poor combustion characteristics and volatility of biodiesel compared to diesel fuel—the lower heating value of biodiesel than diesel oil. The thermal efficiency of biodiesel blends B10, B20 and B30 and up to B100 decreased from 23% to 3%.

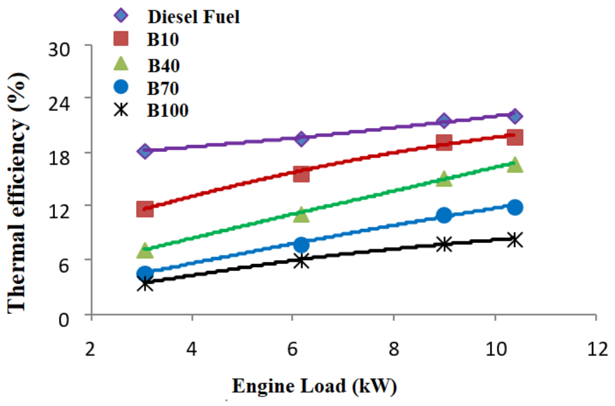

Figure 5. The results of calculating the thermal efficiency of diesel fuel and various bio-diesel fuels under load conditions 3, 6, 9, and 10.5 kW.

Increasing the engine's thermal efficiency is essential to achieve excellent hauling efficiency. The potential for increasing transport efficiency and reducing CO2 comes from the machine's three operating parts, which have different applications. By examining the energy balance of the vehicle, it was found that at low vehicle speeds to less than 35 mph). Engine losses dominate the total energy consumption. At moderate speeds of up to 55 mph, tire friction dominates. At high speeds, the impact on the aerodynamic resistance dominates. Linehaul, vehicle, engine and operations applications have roughly the same share (33%) in potential efficiency improvements. However, vocational applications such as dump trucks are potential. The operation can be reduced by about 10% each, and the machines can be increased up to 80%. Similar studies also Diesel/biodiesel blends of 10 to 40% show a demonstrated increase in thermal efficiency and specific fuel consumption compared to conventional diesel (Singh et al., 2018). On-road diesel engines have approximately 42% brake thermal efficiency at full load, with 28% of fuel energy being wasted as exhaust gases, 28% of fuel energy being vented to the cooling medium as heat rejection to the environment, 2% for heat loss Maroa & Inambao, 2021). There is a strong interaction between heat rejection and exhaust gas energy. Such changes in energy distribution affect waste heat recovery strategies. Achieved 55% engine thermal efficiency by allocating improvement targets for each part of the energy distribution (Xin & Pinkon, 2014).

CONCLUSION

In this study, the diesel engine has been successfully modified so that the combustion chamber's pressure and temperature data readings can be recorded directly. The temperature and pressure data recorded when the engine is running can be analyzed in a graph of the relationship between pressure and temperature and entropy. Thus, the results of this study can be used in the learning process.

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