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Effect of Combustion Chamber Volume and Engine Rotation on Temperature and Compression Pressure of Single Cylinder Diesel Engine

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ABSTRACT

The effect of combustion chamber volume and engine rotation on the temperature and compression pressure of this single-cylinder diesel engine aims to convert the use of diesel fuel in diesel engines into gasoline fuel by utilizing high compression without using the help of spark plugs during ignition. The main focus of the study is to understand the effect of variations in combustion chamber volume and engine rotation on temperature and compression pressure in order to find optimal operating conditions. The General 170fd single-cylinder diesel engine was used as the object of research. The testing tools used include the TC-08 Thermocouple sensor module, the thermocouple sensor, and the pressure gauge to measure the temperature and compression pressure. The research was carried out using various gasket thicknesses, namely 0.6mm, 0.8mm, 1.4mm, 1.6mm, and 1.8mm to vary the volume of the combustion chamber. The data collected was analyzed to determine the relationship between changes in the volume of the combustion chamber and engine rotation to the temperature and compression pressure. The results of the study are expected to provide insight into the ideal conditions for gasoline ignition in diesel engines without the use of spark plugs, as well as contribute to efforts to optimize the use of alternative fuels. The results of the experiment showed that variations in the volume of the combustion chamber and engine rotation had a significant impact on the temperature and compression pressure. The determination of the appropriate temperature and compression pressure is expected to improve the efficiency and performance of diesel engines when using gasoline fuel, thereby reducing operational costs and increasing the flexibility of engine use in various applications. This research makes an important contribution to the understanding of diesel engine modifications for gasoline fuel use, which can be applied without testing exhaust emissions, with a focus on ideal temperature and compression pressure.

Keywords: *diesel engine, compression, temperature, combustion chamber volume, engine speed*

1. INTRODUCTION

Diesel engines are a type of internal combustion engine that is widely used in a variety of applications, from motor vehicles to heavy equipment and electric generators. The main advantages of diesel engines are high thermal efficiency and strong durability [1]. One of the crucial aspects that affects the performance and efficiency of a diesel engine is the compression pressure in the combustion chamber. This compression pressure is affected by several factors, including the volume of the combustion chamber and engine rotation.

The 196cc type 170FD single-cylinder stationary diesel engine has an important role in various industrial and agricultural applications due to its reliability and efficiency in fuel consumption. However, with the rising cost of diesel fuel[2], there is an urgent need to find more economical alternatives, such as the use of gasoline fuel. The use of gasoline in diesel engines is not simple, as the combustion characteristics and physicochemical properties of these two types of fuels differ significantly. Despite its widespread use, technological improvements to diesel engines at this scale continue to be emphasized to ensure efficiency and sustainability in a wide range of industrial applications and the transportation sector [3].

The volume of the combustion chamber is an important parameter that determines the amount of air and fuel that can be compressed in the combustion cycle. The right volume of the combustion chamber can produce optimal compression pressure. The larger the volume of the compression chamber, the less compression pressure is generated. Conversely, the smaller the volume of the compression chamber, the greater the compression pressure produced[4]. In a 1-cylinder diesel engine, variations in the volume of the combustion chamber can have a significant impact given the limited combustion chamber.

Research "Single Cylinder Diesel Engine With Sistem Diesel Methanol Dual Fuel (Dmdf)” To explore the impact of compression ratio variations on the performance of single-cylinder diesel engines using a mixture of methanol and diesel. An increase in the methanol injection ratio achieves optimal performance provided that the engine compression ratio is increased, resulting in a 2% increase in performance [3].

The research "Effect of Residual Volume Capacity on Compression Pressure in 2-Stroke Engine Type Rx-King 135 CC" aims to determine the effect of residual volume capacity on compression pressure. The results showed that the larger the volume of residual space, the smaller the compressive pressure produced, and vice versa. When the volume of the combustion chamber is enlarged by 0.5 mm compared to the standard, the compression pressure is 8.9 kg/cm², and when the volume of the combustion chamber is reduced by 2 mm, the compression pressure increases to 10.5 kg/cm²[5].

The research "Analysis of the Effect of Engine Rotation on Fuel Efficiency of 2Dg-Ftv Diesel Engine" analyzes the effect of engine rotation changes on power in the Cummins KTTA 38 C engine used in the Komatsu PC 3000 coal mining loading equipment. The main goal is to find the optimal engine rotation to achieve power that matches the characteristics of that engine. Testing using dynotest to obtain results related to engine rotation and power generated[6].

The research "Effect of Rotation Changes on Fuel Consumption and Thermal Efficiency of Diesel Engines" aims to understand the torque, power, and fuel consumption in 16-cylinder diesel engines using dynamometers. The results showed that the increased engine revs increased torque, power, and fuel consumption. This study focuses on the effect of engine rotation on torque, power, and fuel consumption in 4-stroke diesel engines[7].

Previous studies have discussed the effect of compression ratio and engine rotation on diesel engines, but the study "Effect of Combustion Chamber Volume Variation and Engine Rotation on Temperature and Compression Pressure in Single-Cylinder Diesel Engines" focuses on the effect of combustion chamber volume and engine rotation variations on compression temperature and pressure in single-cylinder diesel engines. The main variables include the volume of the combustion chamber, engine rotation, temperature, and compression pressure. The study also looked at how engine rotation affects the energy generated from variations in the volume of the combustion chamber.

Engine rotations, or RPM (Revolutions Per Minute), also play an important role in determining the compression pressure. At different engine speeds, the time available for the compression process varies, which can change the pressure dynamics in the combustion chamber. Higher engine revolutions typically increase the speed of the compression process, which can increase the compression pressure, but it can also cause problems such as increased friction and wear of engine components[8].

Engines that are generally produced have a high level of compression pressure in order to achieve their highest performance[9]. Diesel engines, as engines with internal combustion systems, are often chosen by many motorists because of their excellence in fuel efficiency. Unlike other combustion engines that use sparks for ignition, diesel motors use high pressure to compress fuel until an explosion occurs[10].

When the piston is about to reach the upper dead point (TMA), the fuel is sprayed into the combustion chamber through the nozzle, resulting in combustion in the chamber that has been mixed with air[11]. The volume of the combustion chamber is a crucial factor that forms the combustion characteristics, compression pressure, and temperature in the engine. The combustion performance of the engine is greatly influenced by several factors, including the quality of the fuel and the level of compression pressure of the engine itself.

This research aims to fill the knowledge gap related to the operation of a 196cc type 170FD single-cylinder diesel engine using gasoline. To achieve this goal, the research will conduct systematic testing to determine optimal operating conditions. The main focus of the research is to understand the relationship between variations in combustion chamber volume, engine rotation, temperature, and compression pressure. It is hoped that through this test, it will allow diesel engines to operate on gasoline fuel smoothly and optimally.

The results of this study are expected to make a significant contribution to efforts to optimize the use of alternative fuels in diesel engines. By successfully finding the appropriate pressure and temperature for gasoline use, engine operating costs can be reduced, given the relatively cheaper price of gasoline compared to diesel. In addition, the use of gasoline fuel can increase the flexibility of the engine in a variety of applications, both in the industrial and agricultural sectors, without sacrificing engine performance and reliability.

The study is also expected to provide precise test data, which can be used as a basis for further modifications to diesel engines that want to run on gasoline. This data will be invaluable to engineers and researchers focused on improving machine efficiency and reducing operational costs. The main focus of the study remained on the ideal compression temperature and pressure, without testing the exhaust emissions, thus providing a clear view of the modifications required for the fuel transition in a 196cc single-cylinder diesel engine type 170FD.

2. RESEARCH SIGNIFICANCE

This study focuses on the influence of variations in the volume of the combustion chamber and engine rotation. The volume of the combustion chamber will affect the compression pressure and also the temperature generated in the compression chamber in the combustion chamber of the engine. The volume of the combustion chamber as a parameter will be changed using several variations of cylinder head gaskets of different thicknesses. Temperature data collection in the combustion chamber will be carried out at the initial start, the parameter used when testing the temperature data of the compression temperature adheres to the variation of the volume of the combustion chamber. Gaskets used as test parameters for variations in the volume of the combustion chamber using thickness include 0.6 mm (standard), 0.8 mm, 1.4 mm, 1.6 mm, and 1.82 mm thick. And for engine rotation, 200rpm and 500rpm will be set at the beginning of the starter. This research aims to utilize single-cylinder diesel engines that are more efficient at low cost because diesel engines will be converted to gasoline fuel. Because unlike other combustion engines that use a spark for ignition, diesel motors utilize high pressure to compress fuel until an explosion occurs, with the rising cost of diesel fuel, there is an urgent need to find more economical and efficient alternatives, such as the use of gasoline fuel[1].

The advantage of this test will test how much the variation in the volume of the combustion chamber is affected by simply adding the thickness of the cylinder head gasket to the resulting compression pressure and the temperature of the combustion chamber.

A. Diesel Engine

A diesel engine is a type of internal combustion engine that uses the combustion of diesel fuel to generate power. Diesel engines are preferred by vehicle users because of their advantages. Over the past two decades, the use of simulation methods in the modeling of internal combustion engines has been steadily increasing. This increase is due to the inherent potential of simulation methods to properly visualize the sequential and random flow structures generated inside the cylinder [6].

B. Engine Gasoline

Gasoline motors, also known as gasoline internal combustion engines, convert the chemical energy from gasoline fuel into mechanical energy to power other vehicles or engines[12]. Its working principle is based on the Otto cycle which consists of four main steps: suction, compression, combustion and discharge. In the suction step, a mixture of air and gasoline enters the cylinder as the piston moves from the upper dead point (TMA) to the lower dead point (TMB). The compression step occurs when the piston compresses the mixture as it moves from TMB to TMA with all valves closed. [8]. In the combustion step, the spark plug sparks a flame to burn a mixture of compressed air and gasoline, producing an explosion that pushes the piston back into the TMB and generates power. The exhaust step then ejects the residual combustion gases as the piston moves back from the TMB to the TMA with the exhaust valve open[13].

Gasoline motors consist of major components such as cylinders and pistons, intake and exhaust valves, spark plugs, crankshaft (crankshaft), and camshaft (nok shaft). The advantages include being responsive and fast, lighter, and lower initial cost compared to diesel motors. However, gasoline motors have lower fuel efficiency, higher exhaust emissions, and require more frequent maintenance[14]. Gasoline motors are widely used in passenger vehicles, motorcycles, garden equipment, and some light industrial applications. With the development of technology, gasoline motors are becoming more efficient and environmentally friendly through innovations such as electronic fuel injection systems and catalytic converters to reduce exhaust emissions.

C. 4 Stroke Motor

A 4-stroke diesel engine produces one cycle of work after four movements, which is equivalent to two crank turns[15]. The schematic of the working principle of a 4-stroke diesel motor can be described as follows.

1. In the Suction Step, the inlet valve opens and the exhaust valve closes, allowing airflow into the cylinder[2].
2. At the Compression Step, both valves close, and the piston moves from the TMB point to the TMA, pressing the air in the cylinder. Five o after reaching the TMA, the fuel is injected.
3. Expansion Steps occur when fuel burns in a cylinder at a high temperature, causing the expansion and pressing of the piston to perform the work until it reaches TMB, with both valves closed.
4. In the Exhaust Step, when the piston is close to reaching the TMB, the exhaust valve opens, while the intake valve remains closed.

As the piston moves towards the TMA, the combustion residue is expelled from the combustion chamber. The end of this step occurs when the piston reaches the TMA. The piston movement scheme in the cylinder on this 4-stroke motor creates a single working cycle [9].

D. Combustion chamber

The pressure and temperature of the combustion chamber in the internal combustion engine play a crucial role in optimizing the combustion process.[16] Combustion chamber pressure is related to combustion speed and efficiency[17], while the temperature of the combustion chamber affects the speed of the combustion reaction and the quality of the combustion results[18].

Basically, the compression process inside the combustion chamber affects the gas pressure[19], and the ideal formula of the gas can provide an idea of that pressure under certain conditions.

If the relationship between the specific volume and temperature for the two ideal gas states has the same specific entropy[20] hence the equation

$$\left(\frac{p_2}{p_1} = \frac{p_{r2}}{p_{r1}} S_1 = S_2 \right) \quad (1)$$

With the equation of the ideal gas state, , the ratio of the specific volume: then based on the 2 states that have the same specific entropy as equation (1) can provide: $v = \frac{RT}{p} \frac{v_2}{v_1} = \frac{RT_2}{p_2} \frac{p_1}{RT_1} \frac{v_2}{v_1} = \frac{RT_2}{pr(T_2)} \frac{pr(T_1)}{RT_1}$

The ratio seen on the right side of the equation serves solely as temperature. this is called relative volume with the symbol Vr(T)

$$\frac{RT}{pr(T)} \frac{RT}{pr(T)}$$

$$0 = c_v ln \frac{T_2}{T_1} + Rln \frac{v_2}{v_1}$$

$$0 = c_p ln \frac{T_2}{T_1} + Rln \frac{p_2}{p_1}$$

With an introduction to the ideal gas relationship: so that this seedling can be completed into: $Cp = \frac{kR}{k-1} Cv = \frac{R}{k-1}$

$\frac{T_2}{T_1} = \frac{{v_1}^{k-1}}{v_2}$, ((2) $S_1 = S_2 , k = constant$)

$\frac{T_2}{T_1} = \frac{{p_2}^{\frac{k-1}{k}}}{p_1}$, ((3) $S_1 = S_2 , k = constant$)

Based on this relationship, the following equations are obtained:

$\frac{p_2}{p_1} = \frac{(v_1)^k}{(v_2)k}$, ((4) $S_1 = S_2 , k = constant$)

By looking at equation (3), it can be concluded that the polytropical process = constant of an ideal gas with a constant k, namely an isentropic process. For n=1 is an isothermal process, n=0 is an isobaric process and n=2 is isovolumic (isometric). pv_k ±[21]

Information:

$T_2 = \frac{v_1^{k-1}}{v_2} x\, T_1, (temperature\ 2)$

$T_1 = 27°C => K$

$= 27 + 273 = 300°K\ (\ 27°C\ )\ dry\ air\ temperature$

$p_2 = Compression$

$p_1 = \frac{\pi}{4} d^2 x\ (L + C)$

$k = constant$

E. Ignition

Ignition is the process of igniting a mixture of fuel and air in an internal combustion engine to produce power.[22] This process is crucial in engine performance, because without effective ignition, the engine will not be able to produce the power required to work[23]. Ignition through high compression pressure is a method used in diesel engines to start fuel combustion. [24] In diesel engines, fuel ignition occurs due to very high compression pressure[25]. This process is different from gasoline engines that use spark plugs to produce sparks.

Pure air is compressed by the pistons in the engine cylinders until it reaches very high pressures and temperatures.[26] The compression level in diesel engines is much higher than in gasoline engines, usually between 14:1 and 25:1.[27] Just before the piston reaches the upper dead point (TMA), diesel fuel is sprayed into a combustion chamber filled with high-pressure hot air[28].

Due to the extremely high air temperature due to compression, diesel fuel automatically burns when sprayed into the combustion chamber. No spark plugs are required to ignite fuel[29].

High-compression ignition in diesel engines has several advantages, including higher thermal efficiency thanks to a larger compression ratio[30], resulting in higher torque at low speeds [31] which is particularly useful for heavy vehicles such as trucks and buses, as well as durability and longevity due to its rugged design and operation at lower engine speeds. However, diesel engines have a drawback, which is noisier[32] and vibrate compared to gasoline engines[33], as well as higher initial costs due to more robust construction and more advanced fuel injection technology.

Ignition through high compression pressure is an efficient and reliable ignition method used in diesel engines. This method utilizes high compression to heat up[34] air to a temperature sufficient to ignite diesel fuel without the need for spark plugs, thus improving thermal efficiency and torque, albeit with some drawbacks such as higher noise and vibration.

F. Compression Pressure

The compression pressure in the engine is the pressure generated by the process of air compression inside the combustion chamber of the engine[35]. This compression process occurs when the piston moves upwards in the engine's working cycle, reducing the volume of the combustion chamber and causing an increase in air pressure inside.[2] Compression pressure has a positive impact on engine performance, where an increase in compression pressure will increase the power produced by the engine.[2] The higher the compression pressure, the greater the potential to generate more power through the engine.

G. Revolution Per Minute

RPM, or "Revolutions Per Minute", is a unit of measurement for determining how fast an object rotates[36]. RPM indicates how many times the shaft or component rotates in one minute[37]. Understanding RPM is very important in the context of an engine because it has a direct effect on the performance and operational characteristics of the machine. In vehicles, RPM is often displayed on the tachometer on the dashboard, helping the driver know when to change gears to optimize engine performance. High RPMs usually indicate the engine is working hard, while low RPMs indicate the engine is working more leisurely. In addition, RPM is also used in various fields of engineering and science to measure the rotational speed of mechanical components or other equipment.

H. Temperature

The temperature in the combustion chamber of an internal combustion engine, such as in a car or motorcycle engine, can be very high.[38] During the combustion process, the temperature in the combustion chamber of a gasoline engine (Otto Cycle) can reach between 2,000 to 2,500 o Celsius (3,632 to 4,532 o Fahrenheit), while diesel engines, which use the principle of compression to ignite the fuel, often reach temperatures between 2,200 ºC and 2,500ºC (3,992 to 4,532º F)[39].

The temperature in the combustion chamber is affected by a variety of factors, including the type of fuel, the air-fuel ratio, the compression pressure, the engine design, and the optimal cooling system [40]. Temperature control in the combustion chamber is essential for performance[41], because too high a temperature can cause detonation (knocking) that damages the engine[42]. Thus, the temperature in the combustion chamber is one of the important parameters that must be controlled to ensure optimal performance and durability of the engine.

3. RESEARCH METHODS

3.1 Installation scheme

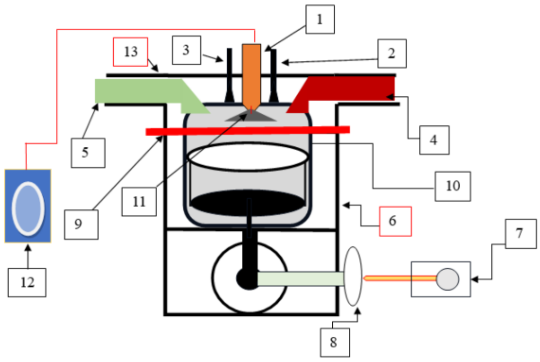

Fig 1. Installation scheme

Whereas: 1. Injector 2. Exhaust valve 3. Intake valve 4. Exhaust 5. Intake manifold 6. Engine block 7. Tachometer 8. Drive pulley 9. Gasket cylinder head 10. Combustion chamber 11. Thermocouple sensor 12. Thermocouple TC-08 module sensor 13. Cylinder Head.

3.2 Material

This study uses a General 170FD type single-cylinder diesel engine with 196cc. This engine is an engine stand type. In Fig. 2, you can see the engine of the General 170FD.

Fig. 1 General 170FD Single Cylinder Diesel Engine

The material used in this study is in the form of gaskets/gaskets with different thicknesses but with the same cylinder circumference. The gasket used can be shown in Fig. 5 below.

Fig. 2 Cylinder head Gasket

3.2 Experimental Procedure

The test will be applied to a single cylinder General 170FD diesel engine, with the test setup as shown in Fig. 6 below. The trial was carried out three trials in two tests. The first test on the effect of cylinder volume variation on compression pressure. With the settings as shown in the image below

Fig. 3 Thermocouple Sensor set up

The second test conducted a test on the engine rotation that was at the initial starter to start the engine. The engine rotation used is at 200rpm and 500rpm. This test also uses variations in the volume of the combustion chamber will be taken 3 times.
For temperature testing in the combustion chamber, the help of a thermocouple sensor will be used which will be placed on the injector hole, but previously it is necessary to make a replica of the injector on the engine and then given a hole for the thermocouple to be installed, then glued using iron glue. The thermocouple will be connected to the TC-08 sensor module which is also connected to the laptop to see the temperature data read by the sensor. The installation of the thermocouple sensor on the machine can be observed in the following figure.

Fig. 4 Thermocouple Sensor Setting

Before conducting the trial, theoretical data was taken first. The results of the data will be compared with factual data.

4. RESULTS AND DISCUSSION

4.1 Compression Pressure Testing

The addition of gaskets has an effect in increasing the size of the volume in the combustion chamber. The test results on the effect of varying combustion chamber volumes show data on the impact of gasket thickness on combustion chamber volume. The data indicates that increasing the gasket thickness will increase the combustion chamber volume and result in a decrease in the engine's compression ratio.
The compression pressure testing, resulting from varying combustion chamber volumes through the installation of gaskets of different thicknesses on the cylinder head, yielded data.
The tests to measure compression pressure were conducted three times for each parameter. The data shows that the

smaller the combustion chamber volume, the greater the resulting compression pressure, and conversely, the larger the combustion chamber volume, the smaller the resulting compression pressure.

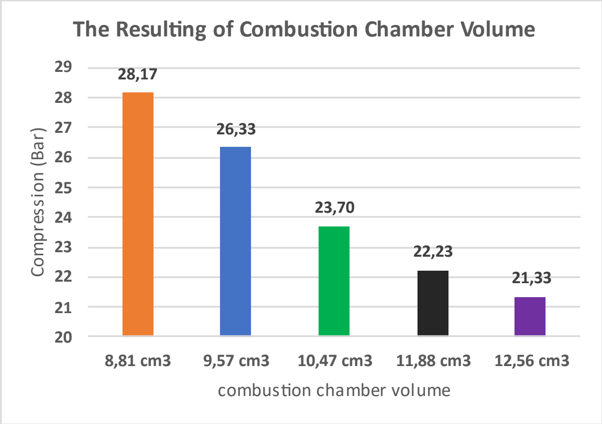

Fig. 5 Compression pressure graph of each combustion chamber volume test

Applying a volume of 8.81 cm³ will result in a compression of up to 28bar. This high compression allows gasoline to ignite without the assistance of the spark generated by the spark plug. Typically, the compression pressure in conventional gasoline engines is only around 9.5 to 15 bar, and even then, ignition requires the spark from the spark plug to occur.

4.2 Combustion Chamber Temperature Testing

Variations in combustion chamber volume also affect the temperature in the compression chamber. From the test results, where the combustion chamber temperature was measured with variations in cylinder gaskets, the following da6ta was obtained:

A. 200 RPM

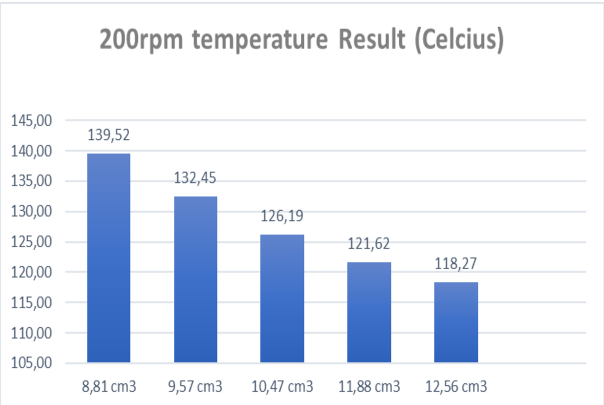

Fig. 6 Combustion chamber temperature test data graph at 200RPM

In tests at an engine speed of 200 RPM, the resulting temperature remained low. At low engine speeds, the piston moves more slowly during the compression stroke. This allows more time for the compressed air-fuel mixture to lose heat to the cylinder walls and cylinder head. Consequently, the final temperature of the compressed air-fuel mixture can be lower compared to higher engine speeds, where compression occurs more quickly and less heat is lost.

B. 500 RPM

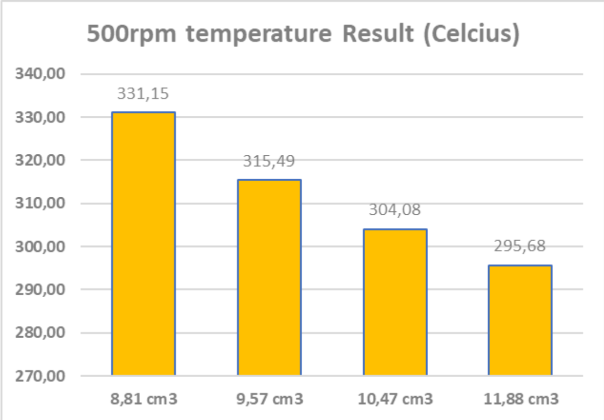

Fig. 7 the Combustion Chamber Temperature Data Testing at 500 RPM

Fig. 7 shows that the highest compression pressure from the smallest cylinder volume results in a high compression temperature. Conversely, if the cylinder volume increases, the temperature inside the combustion chamber decreases. To align with the ignition temperature of gasoline during the initial start, the highest compression temperature is required during testing. By applying a volume of 8.81 cm³, the obtained compression temperature is 348.83°C. This temperature does not reach the autoignition point of gasoline for spontaneous ignition. Generally, the compression pressure in gasoline engines ranges between 150 to 200 psi (10 to 14 bar), with compression temperatures around 250° to 400°C. However, during testing, the engine could start at a temperature of 340° - 355°C. This temperature is adequate for gasoline fuel ignition since if the compression temperature is at or above the gasoline autoignition point, knocking will occur in the engine.

When testing with a combustion chamber volume of 9.57 cm³, the resulting compression temperature was 331.15°C. According to theory, this temperature should be sufficient for gasoline fuel ignition, but test results showed that the slightly larger combustion chamber volume led to decreased compression, affecting the ignition process. The engine could run for a short time, but if the engine temperature became too high, the engine would sputter and eventually stall.

For tests with even larger combustion chamber volumes, the engine would not start at all. This is due to the reduced compression in the engine and the lower temperature resulting from a thicker gasket or an increased combustion chamber volume.

5. CONCLUSIONS

The engine can start using gasoline fuel when a 0.6mm thick gasket is added, increasing the combustion chamber volume to 8.81cm³, and producing a compression pressure of 28 bar. This compression pressure creates a combustion chamber temperature of 348.83°C. At this temperature, the engine can start well without detonation. Testing with an increased volume of 9.57cm³ only allows the engine to run for a short period with the aid of fuel injection into the intake manifold. Tests with volumes of 10.47cm³, 11.88cm³, and 12.56cm³ did not achieve the desired results because the compression pressure and combustion chamber temperature were still low, preventing the engine from starting.

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7. AUTHOR CONTRIBUTIONS

Conception and design: Sigit Prasetyo, Bambang Irawan
Methodology: Sigit Prasetyo
Data acquisition: Sigit Prasetyo
Analysis and interpretation of data: Sigit Prasetyo
Writing publication: Sigit Prasetyo, Bambang Irawan.
Approval of final publication: Bambang Irawan.
Resources, technical and material supports: Bambang Irawan.
Supervision: Bambang Irawan

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