Influence of duration and fuel injection pressure on two stroke gasoline direct injection engine performance

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Abstract. The 2-stroke gasoline engines produce high air pollution because there is fuel wasted directly into the exhaust during the scavenging process. Solution to overcome the problem of pollution and improve engine performance is changing the fuel system into a direct injection fuel system. This study aims to determine the performance characteristics (power and torque) of two stroke gasoline direct injection engine in variations in injection duration and fuel pressure entering the combustion chamber with fixed injection timing 85° before TDC. The timing of fuel injection is carried out by a solenoid valve which is regulated using a disc board mounted on a crankshaft and detected by infrared sensors. Variations in the degree of duration of injection testing are 45°, 55° and 65°, in variations of fuel pressure of 6 bars, 7 bars and 8 bars The tools used for data collection are pressure gauge to measure fuel pressure and a tachometer is used to measure engine speed and engine torque measured by Prony brake. The results of this study indicate that increasing the duration and fuel pressure will increase power but do not directly affect the increase in torque, both because there is a certain duration and pressure which results in maximum performance.

1. Introduction

Minister of the Environment Regulation No. 05 of 2006 article 3 paragraph 1 states the threshold emission levels of old motor vehicle exhaust motorcycles CO levels do not exceed 4.5% and HC does not exceed 12000 ppm [1] requires proper combustion efficiency to improve internal combustion engines that will produce emissions that are environmentally friendly. Currently 2-stroke engines with carburetor fuel systems are increasingly reduced production in the automotive industry. This is largely because the 2-stroke engine has high exhaust emissions [2]. To overcome this high emission, direct injection is now one of the requirements for modern automotive 2-stroke engines [3]. Direct injection technology allows homogeneous combustion with the right mixture so that it reduces exhaust emissions, improves fuel efficiency and increases engine power [4].

Like a 4-stroke direct injection gasoline engine, the ability to ignite the mixture is affected by the choice of injection time and injection duration. Most research on motor fuel systems has focused on the use of 4-step engine fuel systems [5]. However, only a few studies have focused on the use of fuel injection systems as a fuel mixing system on two-step motors and generally still use conventional fuel injection systems [6,7]. a 2-stroke gasoline engine is an engine that completes its cycle in two piston steps or one crankshaft revolution [8]. Meanwhile, the shortcomings in this engine are producing high air pollution. This happens because of the lubricants and fuel was not burn at scavenging process which escapes participate disposed of directly through the exhaust port [9]. To overcome these problems, then
one way is to change the 2-stroke gasoline engine into an engine that uses a direct injection fuel system, then this engine does not occur in the waste of fuel wasted during the rinse steps so that this engine does not cause excessive exhaust emissions [10]. The solution to produce good engine performance is to use a direct injection device for mixing the fuel system into the engine [11].

Preliminary studies using simulations of 2-stroke engines with direct injection with gas fuel promise to increase fuel energy conversion [12]. Furthermore, a 2-stroke direct injection engine experiment using gas fuel has also been carried out [13,14]. However, these studies have drawbacks that the gas fuels used are difficult to obtain at refueling sites unlike liquid fuels. Therefore, there needs to be research that uses liquid fuel that is easy to obtain is gasoline fuel. Initial studies were limited to being able to operate the engine without known performance because variations in fuel pressure and the effect of timing injection on engine speed using gasoline fuel have proven to be successful [15]. Engines with fuel injection systems, injection time and length of injection time (injection duration) greatly affect the combustion ability of the mixture, engine performance and fuel consumption, especially in small equivalent operations since the time range between injection time then injection duration and ignition time then duration and duration ignition of the fuel will affect the formation of the mixture in the cylinder [16]. Therefore, this research will concentrate on testing the performance of 2-stroke direct injection gasoline engines on variations in duration and pressure of fuel injection.

2. Methods
The research method used in this study is an experimental method. The tests are based on the following general assumptions: (1) The condition of temperature and humidity is assumed to be constant; (2) Machines used by two-step machines; (3) The results sought are only engine speed and torque; (4) The observed performance is the duration of the injection and the pressure of the fuel that enters the combustion chamber at the injection timing fixed 85° before the top dead center (TDC).

![Figure 1. Experimental set up.](image-url)

The experimental set up used can be seen in Figure 1. The engine tested was a 2-stroke gasoline engine with a cylinder diameter 52 mm, piston stroke 51 mm, and a displacement volume of 110 cm³ that had been modified into a gasoline direct injection engine, on the cylinder head made injector mounting holes and spark plug holes that will be placed next to each other. Then a solenoid valve is placed in the fuel channel at the front of the injector as a pressurized fuel intake valve into the engine. The injection time and injection duration settings are regulated by an electronic module that regulates the open-close of the
injector. This is done through a process whereby, translucent infra-red light passes through the disc board when the light begins to be received as injection time then the duration of the light then the interrupted light is regulated by the angle on the disc board as input, and the opening and closing of the injector solenoid as output. The crankshaft is connected using a fixed clutch with a disc which functions as a Prony brake. The injection time is 85° before TDC. The injection duration angle variation is 45°, 55° and 65° while the fuel pressure used is 6 bar, 7 bar and 8 bar. Tests are carried out when the engine reaches the optimum revolution then given a loading (brake pressure) with Prony Brake. Then the crankshaft rpm is measured as a result of the brake torque that is carried out continuously before the engine turns off.

3. Results and discussion
Figure 2 shows that at 8 bar fuel pressure in the injection duration angle 45°. After passing the peak power, the 2-stroke direct injection engine power decreases again along with the decrease in torque when the engine speed increases. This relates to the characteristics of piston engines that have maximum volumetric efficiency at a certain engine revolution speed, which is the fuel pressure of 8 bar has peak torque at 1300 rpm.

![Figure 2](image1.png)  
Figure 2. Comparison of torque and power at 8 bar fuel pressure in the injection duration 45°.

![Figure 3](image2.png)  
Figure 3. Comparison of torque and power at 7 bar fuel pressure in the injection duration 45°.

Similar torque and power characteristics with 8 bar fuel pressure variation also occur with 7 bar and 6 bar fuel pressure variations at an injection duration angle of 45°. As shown in Figure 3. at 7 bar fuel pressure which has a peak power and torque at 1379 rpm engine revolution. However, when the rotation increases, both torque and power will decrease until engine turns off. At 6 bar fuel pressure the 2-stroke direct injection engine gets peak power and torque at 1292 rpm as shown in figure 4. Based on Figures 2, 3 and 4, it can be seen that at variations of the 45° duration angle, even though the higher fuel pressure produces the same torque at 6 and 7 bar pressure and has dropped at 8 bar pressure, the peak torque occurs in an increasingly revolutionary increases with increasing fuel pressure. Because power is a function of the torque multiplication and the crankshaft revolution of the engine, this causes the power generated to increase with increasing engine revolution.
Figure 4. Comparison of torque and power at 6 bar fuel pressure in the injection duration 45°.

Figure 5. Comparison of torque and power at 8 bar fuel pressure in the injection duration 55°.

Figure 5 shows that at 8 bar fuel pressure at an injection duration angle of 55°. After passing the peak performance, as happened in the angle of injection duration 45° (figures 2, 3 and 4), then when the engine revolution increases, both torque and power will drop.

Figure 6. Comparison of torque and power at 7 bar fuel pressure in the injection duration 55°.

Figure 7. Comparison of torque and power at 6 bar fuel pressure in the injection duration 55°.

At 7 bar fuel pressure at an injection duration angle of 55° shown in figure 6. Shows that the highest torque is 38.85 Nm at 1261 rpm and peak power of 6.59 kW at 2268 rpm engine revolution. Figure 7 shows that at 6 bar fuel pressure at an injection duration angle of 55°, the peak performance at engine revolution is 1683 rpm with a power of 4.89 kW and torque of 33.3 Nm at 1383 rpm. Then it will come back down and before the engine turns off. Variation of the injection duration angle of 55°.

Figure 8. Comparison of torque and power at 8 bar fuel pressure in the injection duration 65°.

Figure 9. Comparison of torque and power at 7 bar fuel pressure in the injection duration 65°.
Comparison of torque and power at 6 bar fuel pressure in the injection duration angle 65° shown by figure 8, where the peak performance occurs in the engine revolution range of 1940 rpm to 2327 rpm for power that is 6.76 kW and 33.30 Nm of torque at 1940 rpm. After passing the peak performance, both the torque and power of 2 stroke direct injection engine as in the previous variations will decrease again along with the increase in engine revolution. Figure 9. shows that at 7 bar fuel pressure, the highest performance was on the 1897 rpm engine revolution where the power was 6.61 kW while the torque was 33.30 Nm. After that the performance will decrease when the engine revolution increases and ends at 2507 rpm at 1.46 kW power and 5.55 Nm of torque. The fuel pressure is 6 bar at an injection duration angle of 65° both of which the highest torque is 33.30 Nm and a peak power of 6.06 kW at the similar engine speed of 1740 rpm (fig. 10). Then it will drop back and before the engine turns off it has 1.30 kW of power and 5.55 Nm of torque at 2233 rpm.

At this angle variation of the injection duration of 65°, the variation of fuel pressure does not affect the peak torque produced by the engine, this is indicated where the peak torque is always the same at 33.3 Nm. However, the variation of fuel pressure affects the peak power produced by the engine, i.e. the higher the fuel pressure, the greater the power produced. This is because even though the torque is always the same, the higher the fuel pressure causes the highest torque to occur in the higher engine revolution as well. This is related to that the power is proportional to the product of torque and engine shaft revolution.

The engine torque is affected by the air fuel ratio, the richer of fuel mixture, the greater the torque produced. Figure 11 shows that the peak torque produced by the engine is more influenced by the angle of the duration of the fuel injection than by the fuel injection pressure. this means that the amount of fuel injected into the combustion chamber is more affected by the length of time the fuel is injected
which is here represented by the angle of injection duration. However, both the variation in pressure and the angle of the duration of the fuel injection affect the peak power produced by the engine as shown in Figure 12. which the higher the fuel pressure, the greater the power produced, as well as the greater the angle of the injection duration of the fuel the power produced is also greater. This is because even though torque is not too affected by fuel injection pressure, the higher fuel pressure causes the highest torque to occur at higher engine speeds as well. This is related where the power is a function of the multiplication of torque and revolution of the engine shaft, therefore the power generated will increase at both the pressure and angle of the higher fuel injection duration. Based on figures 11 and 12, the maximum power and torque obtained on the 2-stroke direct injection engine is 6.76 kW at 1940 RPM engine revolution with 33.30 Nm of torque at 65° angle and 8 bar fuel pressure at 85° injection timing angle before TDC.

4. Conclusion

some conclusions that can be drawn from testing and processing data on the performance of the 2-stroke direct injection engine system with variations in the injection duration angle and fuel pressure include:
1. The peak torque produced by the engine is more influenced by the angle of the duration of the fuel injection than by the fuel injection pressure.
2. Both the variation in pressure and the angle of the duration of the fuel injection affect the peak power produced by the engine.
3. The maximum power and torque obtained on the 2-stroke direct injection engine is 6.76 kW at 1940 RPM engine revolution with 33.30 Nm of torque at 65° angle and 8 bar fuel pressure at 85° injection timing angle before TDC.

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