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# Effect of Swirl Generator Intake Manifold on Engine Performance using Ethanol/Gasoline Blend

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**ABSTRACT----** ***This study evaluates the effect of adding swirl generators to the intake manifold aims to make the turbulent air-flow on intake manifold and the increased mixture quality of fuel with air will also improve combustion process on spark ignition engine.***

***The experiment is done on a port injection gasoline engine, four-stroke, SOHC four cylinder connected to the engine dynamometer, which is used to measure the power.***

***An engine using ethanol blend fuel has higher fuel consumption, E10 fuel consumption average increase is 12%, and E20 fuel consumption increase is 14%. Performance in relation to the torque, E10 in the case Half Open Throttle at 2000 rpm reduces the engine torque by 3.8 %, at 4000 rpm the engine torque is reduced by 1.6%. E10 in the case of Wide Open Throttle at 2000 rpm reduce the engine torque by 3.4%, and at 4000 rpm reduces the torque by 1.2%. In the case of E20 at Half Open Throttle and rpm 2000 the engine torque reduces by 5.8%, and at 4000 rpm increases by 2.7%.***

***The addition of a swirl generator will increase the engine performance in the case of E20 at Half Open Throttle. The average engine torque increases from 10 until 13 %, in the case of Wide Open Throttle the engine torque increases by 9%. In the case of E10 with Half Open Throttle the engine torque increases by 9%, and with Wide Open Throttle increases by 8,5%.***

**Keywords----** port injection gasoline engine, ethanol fuel, engine performance, swirl flow.

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## 1. INTRODUCTION

The air–fuel mixture process in the combustion chamber greatly affects port injection engine performance. In the port injection engine, gasoline as fuel is injected into a manifold and will be mixed with air. The fuel injected turns into a fuel film, vapor, and drop lead. A good intake manifold design can improve the process of changing liquid fuel into vapor. Fuel with steam will more easily mix with air, thus improving the mixing process.

Combustion is the most important process that takes place in a spark ignition (SI) engine, through which chemical energy of the fuel is converted into sensible internal energy of the cylinder charge (Bayraktar 2007). During this process, a turbulent flame, which is roughly spherical in shape, propagates across the combustion chamber and burns the premixed air–fuel mixture (Tagalian 1986; Namazian et al. 1980). Therefore, combustion can be considered a turbulent flame propagation process. Details of the flame propagation have a substantial effect on combustion, and therefore on the energy conversion process (Gatowski et al. 1984). If the flame propagation becomes faster (i.e. faster burning is achieved) more efficient engine operations can be obtained.

Complete vaporization and mixing of the air charge are probably never achieved in any of the carburetor or manifold injection systems. This means that the charge entering the cylinder contains fuel droplets as well as inhomogeneous mixtures of fuel vapor and air. Tests in the laboratory, where complete premixing of the charge can be accomplished prior to it's entering the engine, did not show substantial improvement in engine performance except at very lean conditions and burning cold start. However, the low-quality mixture tends to increase the rate of deposit build-up in the cylinder. Liquid fuel droplets that enter the cylinder vaporize rapidly during the compression stroke, and the highly turbulent flow within the cylinder promotes rapid mixing. However, during cold starting, liquid that reaches the chamber surfaces form a layer which does not vaporize and mix, thus making the gas-phase mixture leaner at the time of ignition.

Swirl is often imparted to the charge as it enters the cylinder, causing the droplets to orbit the cylinder and affecting the pattern of turbulence. The term 'swirl' is a somewhat generic term. Typically, swirl is essentially a solid-body rotation of gas around the cylinder bore axis. However, not all swirling flows are constant angular velocity flows. In addition, the chamber geometry and combustion distort and change the original swirl velocity profiles. Recently, a more complex inlet configuration which diverts some of the airflow, causing swirls with less pressure drop than conventional-shaped port, has shown promise for lean engine operation. Use of the four valves, heads has allowed one port to be straight, giving tumble flow, and another inlet port is shaped to give swirl.

The swirl ratio and the fluid motion can have a significant effect on air–fuel mixing, combustion, heat transfer, and emissions. It has been shown that small, high-speed, direct-injection diesel engines require an intake swirl ratio of 10 or higher when operating under part-load conditions (Inoue et al. 1980). Hence, it is important to design intake systems that can generate high swirl ratios. It can be achieved by using two or four intake ports arranged in a tangential configuration, or by using helical ports (Inoue et al. 1980) and/or shrouded intake valves.

The addition of a swirl generator in the intake manifold affects airflow in velocity, mass flow rate, and flow shape. This change will affect the fuel film and fuel vapor droplet. To determine the effect, the development of the intake manifold (van intake manifold) on engine performance, the experiment was carried out using the standard intake manifold and intake manifold using a swirl generator. The fuels used in this test were gasoline and ethanol/gasoline blends. In this section, only one type of vane intake manifold is tested. The type selection and angle attack of a swirl generator on the intake manifold assuming the results of the optimization were described in the previous section. The type of swirl generator used in the testing of engine performance is the concave type and the angle attack is 6 degrees.

The addition of a swirl generator to an intake manifold will increase an airflow restriction. Increase restriction will be influenced at airflow in the combustion chamber. This is consistent with **Error! Reference source not found.**. The addition of a swirl generator will reduce the air–fuel ratio. It shows the decrease in the air entering into the combustion chamber. In addition to lowering the airflow, the use of a swirl generator in the intake manifold will improve the angular speed of air that will enter the combustion chamber. Increased angular speed cause swirls in the combustion chamber increases.

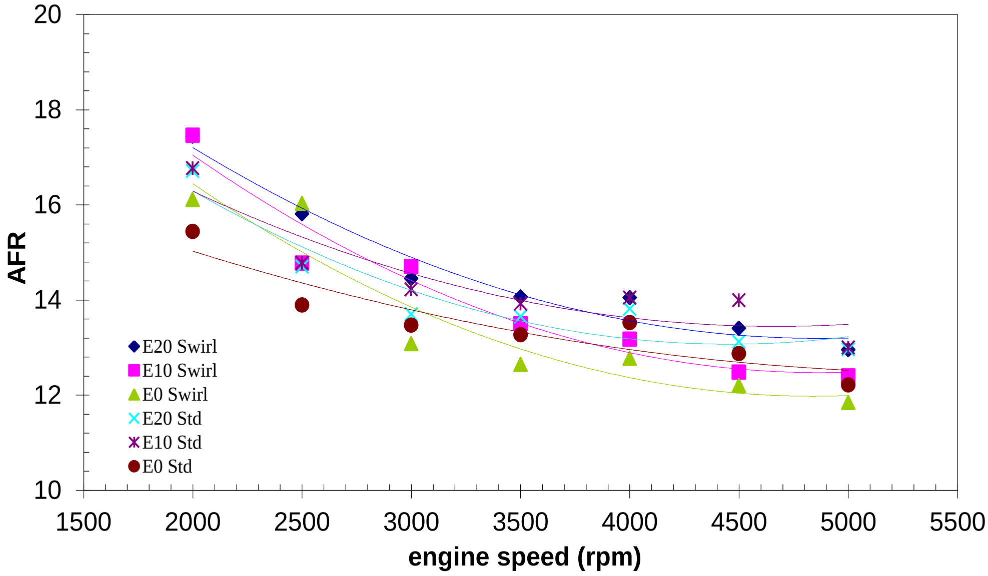
Decreases in airflow and increased angular speed have an effect on the combustion process with gasoline and an ethanol/gasoline blend. The results of this study indicate the use of a swirl generator intake manifold improves engine performance, torque, power, and fuel consumption with both gasoline and ethanol/gasoline blends.

## 2. EFFECT OF SWIRL GENERATOR INTAKE MANIFOLD AT AIR - FUEL RATIO

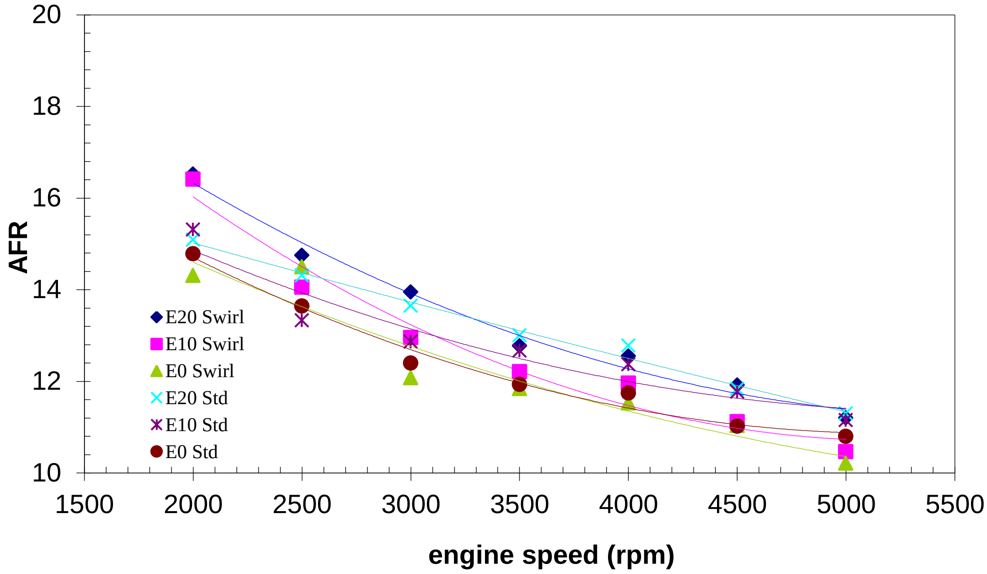
The use of a swirl generator intake manifold will affect the amount of air that enters the combustion chamber. The addition of a swirl generator in the intake manifold greatly affected the flow of air into the combustion chamber. It can be seen by changing the air–fuel ratio. The influence of a swirl generator in the intake manifold to the air–fuel ratio with a different fuel is shown in Figure 1. show that the low-speed engine with swirl generator intake manifold has higher air–fuel ratio than the standard intake manifold. With gasoline fuel, the use of a standard intake manifold at engine speed 2,000 rpm has an AFR of 15.44 and an increase of 0.67 when using the swirl generator intake manifold. This improvement is present in E0 fuel, and increases in E10 and E20 fuel. Increasing the air–fuel ratio means the air–fuel mixture has more oxygen content and vice versa. Increasing the air–fuel ratio at low speeds causes the amount of fuel entering the combustion chamber to be lower; thus, with the same amount of air, the air–fuel ratio will increase. The mass flow rate of fuel is lower when using the swirl generator intake manifold at a low speed.

Air–fuel ratio will decrease with increasing engine speed. This decline will be greater when using a swirl generator engine intake manifold. This can be seen at engine speeds greater than 3,500 RPM; a swirl generator intake manifold as the air–fuel ratio lowers. The air–fuel ratio decreases at high speed due to the decrease of airflow through the combustion chamber. The addition of a swirl generator in the intake manifold results in increasing resistance in the intake manifold; thus, the amount of air entering the combustion chamber is reduced.

In addition to high speed, the addition of a swirl generator in the intake manifold will be very influential in the WOT. When compared with HOT, the air–fuel ratio at the WOT will be very different. At HOT, the addition of a swirl generator changed the airflow minimally with the standard intake manifold. At the WOT, the addition of a swirl generator created a richer air–fuel ratio. The decrease of the air–fuel ratio is the result of the addition of a swirl generator that obstructs the rate of air into the combustion chamber. As shown in the previous section, the addition of a swirl generator in the intake manifold causes the airflow to decrease. As with the high speed, WOT on the speed of air entering the combustion chamber increases. Moreover, as air speed increases, the resistance to the airflow will be greater, whereas at low speed or at HOT, airflow velocity is less and therefore less resistant.



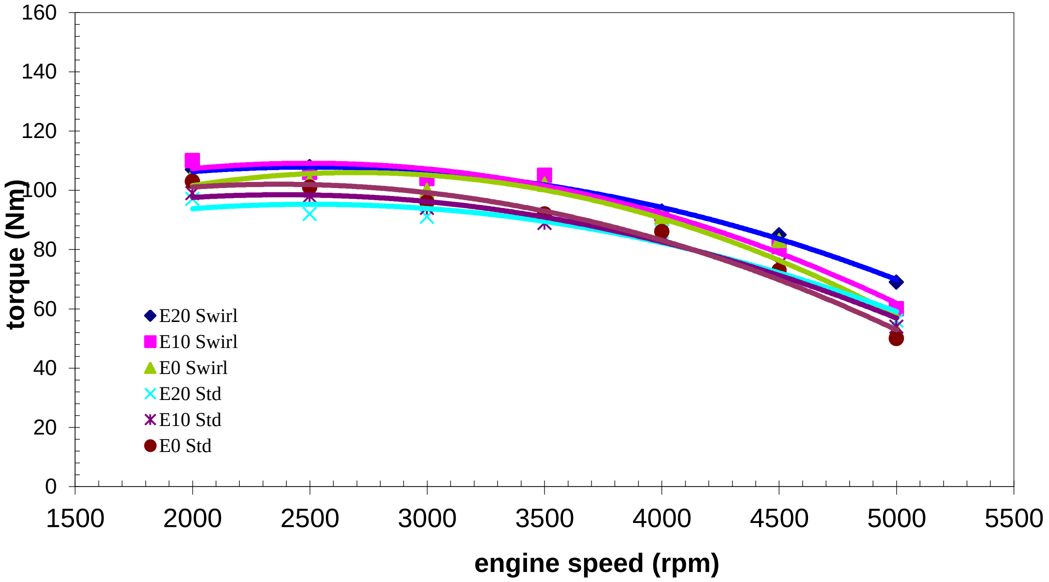

A. Wide open throttle



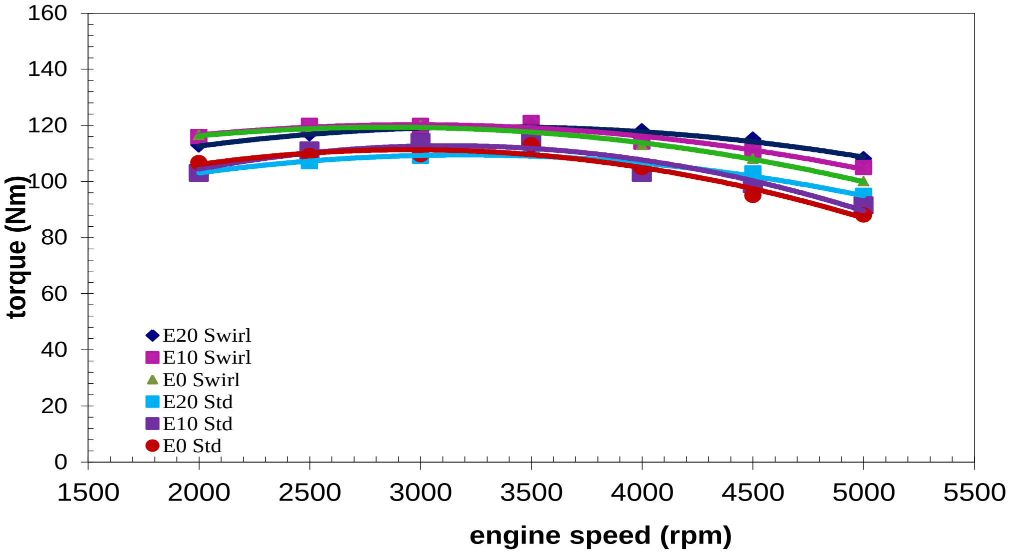

B. Half open throttle

**Figure 1** Effect of intake manifold using swirl generator at the airfuel ratio

## 3. EFFECT OF SWIRL GENERATOR ON BRAKE TORQUE




**A.**Half open throttle




**B**. Wide open throttle

**Figure 2** Effect of swirl generators intake manifold to engine torque

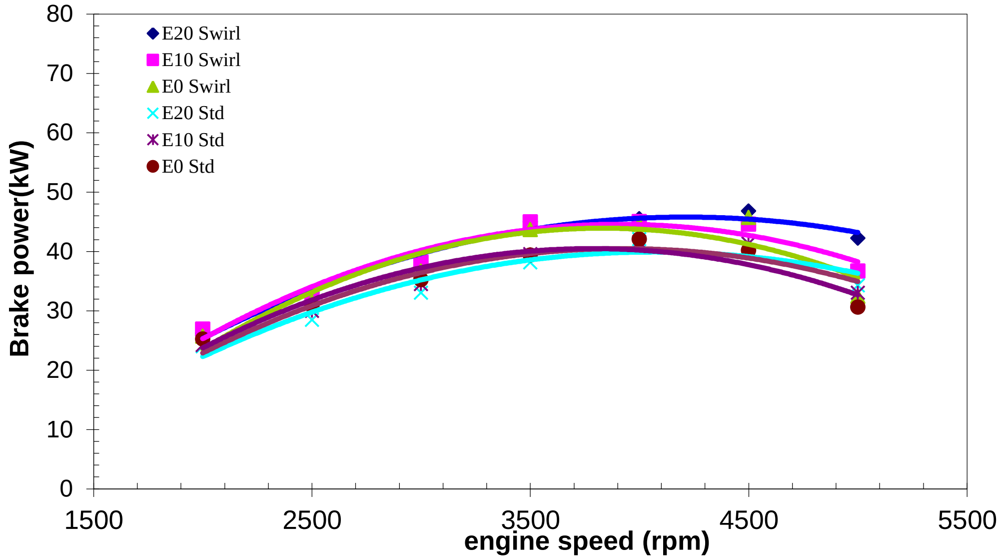
Figure (A) and (B) depict the effect of a swirl generator intake manifold on engine torque and power, The torque is generated by the engines with the standard intake manifold and swirl generator intake manifold at full load and HOT. The engine with a swirl generator intake manifold has a greater torque and better BSFC.

In gasoline fuels, the addition of swirl generators to the intake manifold at an engine speed of 2,000 RPM will increase engine torque by 9.1846298%; at 4,000 RPM, engine torque increased by 13.68421%. Improved engine torque not only occurs with gasoline fuels, as shown in Figure 2. but also with the ethanol/gasoline blend. E10 increased torque by 10.67961% to 12.62136%, while E20 increased torque by 9.708738% to 14.56311%. E20 has increasing engine torque at higher rates than other fuels when using a swirl generator intake manifold.

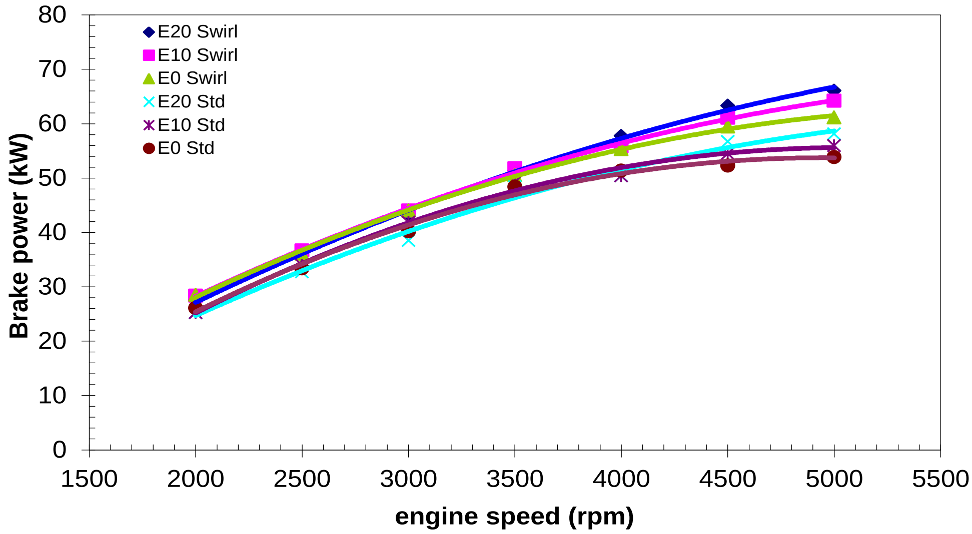
Figure 2 (B) showed that the swirl generator intake manifold, produces greater torque. Increases in engine torque are caused by swirl flow and air–fuel ratio. The process of combustion with swirl and turbulence intensity on the mass fraction burned, burn rate, and burn duration. High swirl flow increases burn duration. Swirl flow has an important effect on the engine combustion. According to the increased and maximum value of burn rate increased (Yamamoto et al. 1984), this occurs because burn durations of rich mixture are faster than lean mixtures. The flame speed seems to reach its maximum at a slightly rich mixture and falls off on the other side (Stephen 2000). At low values, lambda releases with air–fuel ratio, and the combustion process is both fast and stable; thus, the swirl ratio has only a small impact on burn duration. Furthermore, with higher swirl ratios, most of fuel is distributed near spark plug. Thus, it can be concluded that a higher swirl ratio will have the best stratification and shorter burn duration.

## 4. EFFECT OF SWIRL GENERATOR ON ENGINE POWER

In addition to affecting the generated torque, use of intake manifold swirl generators have a significant effect on the power generated by the engine, either at HOT or WOT. At WOT, the power generated by the engine experienced a greater increase in comparison with both HOTs at low speed and at high speed, as shown in Figure (A). By operating the engine at the WOT or at high speed, the velocity of air passing through the swirl generator will be higher in comparison with HOT. These occur as a result of variation of the air velocity into the combustion chamber; the swirl generated will be higher. Despite the swirl generator, the air resistance increases, but with a swirl of higher engine power it can be improved.




A. Half open throttle



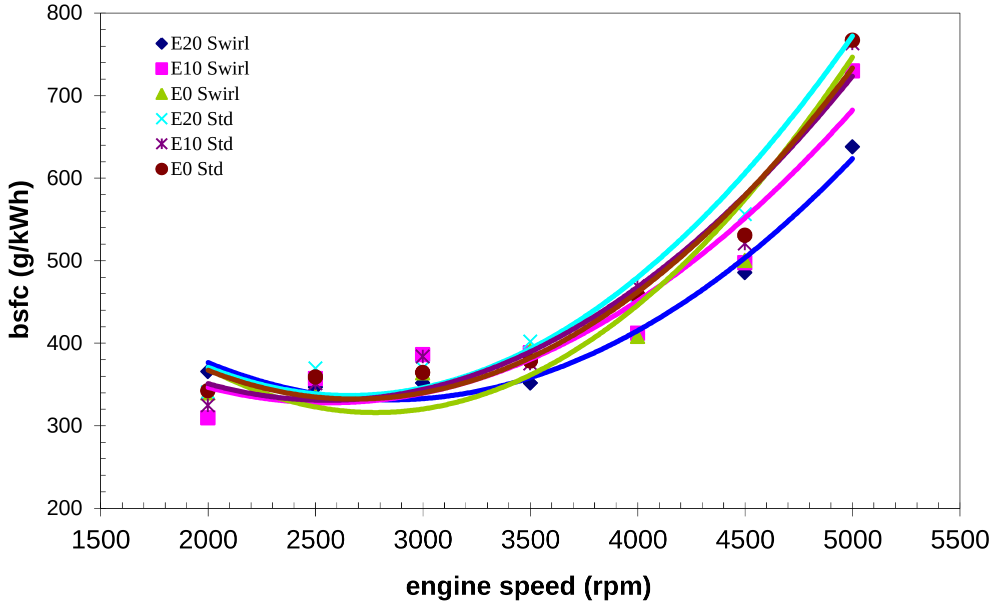

B. Wide open throttle

**Figure 3** Effect of swirl generators at intake manifold to engine power

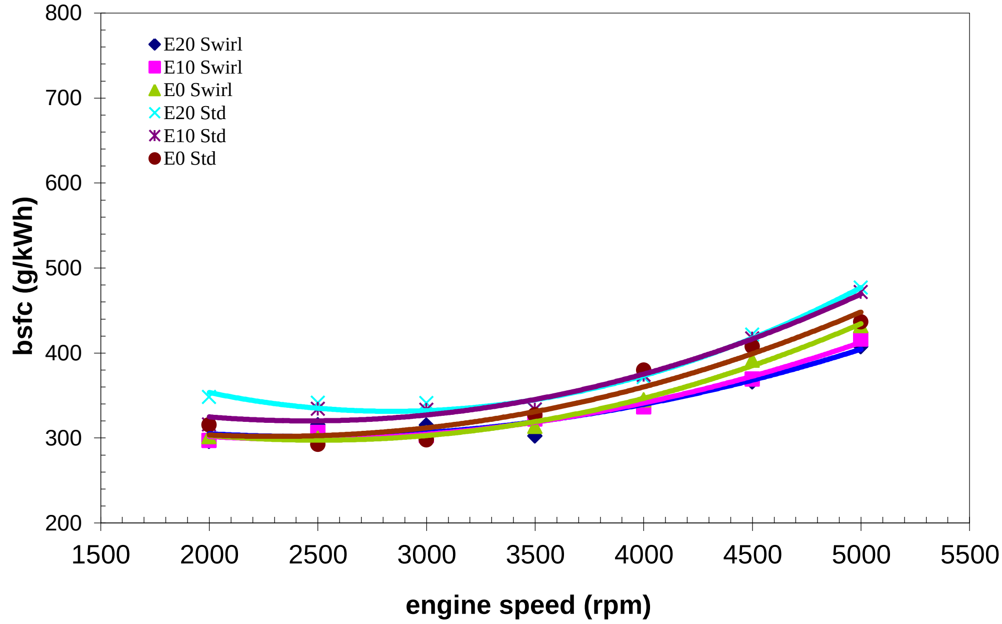
Figure 3, illustrates the change of power generated by the engine's swirl generator intake manifold. At low speed, engine power is increases by 9.1% to 12.6% on average; at high speed, engine power increases more significantly by 11% to 13%. The highest increase in the gasoline fuel occurs at an engine speed of 4,500 RPM, followed by E10. Increased engine power and torque in the swirl generator intake manifold is caused by two conditions: the airflow entering into the combustion chamber and the swirl number. The increase is a result of the effect of mixture stratification combined with swirl motion. A faster burning rate occurs with higher oxygen concentration, which indicates more complete combustion.

## 5. EFFECT SWIRL GENERATOR INTAKE MANIFOLD ON FUEL CONSUMPTION

The BSFC is one of the most important parameters of engine performance. It is a measurement of an engine's efficiency. However, combustion stability increased along with the air–fuel ratio, lengthening the burn duration; large cycle-by-cycle variation caused the BSFC to increase. The swirl generator intake manifold with high swirl charge motion has clearly reduced fuel consumption at WOT and with a high-speed engine.




A. Half open throttle




B Wide open throttle

**Figure** Error! No text of specified style in document.**.** Effect of swirl generators to specific fuel consumption

Increasing swirl flow in the combustion chamber using swirl generator intake manifold resulting combustion process becomes faster. Figure Error! No text of specified style in document.**.** (A) shows the swirl generator intake manifold causes engine fuel consumption with ethanol/gasoline blend. In the picture above shows that by increasing the content of ethanol in fuel can reduce fuel consumption. It can be seen between gasoline fuel, E10 and E20. By using 20% ethanol fuel, has low BSFC.

Figure Error! No text of specified style in document.**.** illustrates the differences in fuel consumption between HOT and WOT and the low speed and high speed. Use of the intake manifold swirl generator fuel consumption only slightly affected at HOT. At low-speed conditions with a swirl generator, the fuel consumption did not change significantly. Fuel consumption decreased with increasing engine speed. This is evident when the engine speed is above 3,000 RPM using E20, resulting in greatly reduced fuel consumption. At HOT, the addition of a swirl generator in the intake manifold is not enough to change the airflow inside the intake manifold to form a swirl and turbulent airflow in the combustion chamber during the intake stroke. Thus, the addition of a swirl generator will create higher resistance in the intake manifold

At high speed or at WOT, the addition of a swirl generator has an enormous influence on fuel consumption. Basically, WOT at high speed and fuel mixture in the combustion chamber is better than HOT. Furthermore, the addition of a swirl generator in the intake manifold causes airflow into the combustion chamber to be more turbulent. Increasing swirl in the combustion chamber will increase the mixing process of air and fuel; thus, the fuel mixture will be more homogeneous

## 6. CONCLUSIONS

This investigation deals the development of the intake manifold with a swirl generator to increase engine performance on ethanol fuel blend. The experiment is done to determine how the addition of ethanol in the fuel affects the engine performance and emissions. After knowing the effect of ethanol on engine performance, the research proceeded with the development of the intake manifold with a swirl generator to get a form that is more turbulent flow in the combustion chamber. The study next focused on the influence of the use of a swirl generator on engine performance. The research was done using a standard intake manifold and an intake with the addition of a swirl generator. The following conclusions have been reached.

- An engine using ethanol blend fuel has higher fuel consumption, E10 fuel consumption average increase is 12%, and E20 fuel consumption increase is 14%..
- Performance in relation to the torque, E10 in the case Half Open Throttle at 2000 rpm reduces the engine torque by 3.8 %, at 4000 rpm the engine torque is reduce 1.6%. E10 in the case of Wide Open Throttle at 2000 rpm reduce the engine torque by 3.4%, and at 4000 rpm reduces the torque by 1.2%. In the case of E20 at Half Open Throttle and rpm 2000 the engine torque reduces by 5.8%, and at 4000 rpm increases by 2.7%. Ethanol blend as fuel will have better performance when the engine works at high engine speed or full load.
- The addition of a swirl generator will increase the engine performance in the case of E20 at Half Open Throttle. The average engine torque increase from 10 until 13 %, in the case of Wide Open Throttle the engine torque increases by 9%. In the case of E10 with Half Open Throttle the engine torque increases by 9%, and with Wide Open Throttle increases by 8,5%.

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