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# An Experimental Study of Variable Throttle Opening Effects on the Performance and Emission of (SI) Engine

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**Abstract:** Performance, emissions and fuel consumption of a four-stroke, four-cylinder engine were experimentally measured for the Mitsubishi model 4G15 spark ignition engine Multipoint Injection (MPi). The objective of this study is to determine the effect of the gasoline RON95 towards emission, engine output and fuel consumption. It was predicted that the performance and emission should be affected by the opening of throttle valve. Variable parameters were used in this study such as engine speed and percentage throttle opening respectively on 4000 and 4500 as well as 25%, 50%, 75% and 100%. Results show that using RON95 petrol at engine speed 4000 rpm is more suitable than 4500 rpm.



## 1 Introduction

Since the invent of the internal combustion engine in the late of 19$^{th}$ century, a great number of research studies have been conducted to improve the engine performance, decrease the engine fuel consumption and reduce the unwanted exhaust emissions. The fuel is one of most important factor affecting the engine performance. For Spark Ignition (SI) engine gasoline, the octane number is one of the most important parameters determining the quality of gasoline. The octane number of a gasoline is a measure of its resistance to detonation. Also the amount of opening throttle has a significant influence on the exhaust emissions, engine performance and detonation and has been investigated by several researchers. RON 95 Petrol has been introduced in Malaysia. Nowadays, there are many petrol stations especially PETRONAS and Shell already provide the RON 95 grade of petrol. The meaning of RON is the stands for Research Octane Number rating for unleaded petrol. It determines the petrol`s `anti-knock` quality or resistance to pre-ignition or detonation as it burns in the combustion chamber. Knocking occurs when the fuel-air mixture in the cylinder explodes instead of burning in a controlled way [1]. This shockwave moves within the combustion chamber, and creates a metallic pinging Octane quality is one of the many properties of fuel that is often associated with power and improved engine efficiency that is measured by the international standard for fuel, RON. RON 95 helps us to have better environment.

In a traditional spark ignition gasoline engine, the throttle body is the part of the air intake system that controls the amount of air that flows into an engine's combustion chamber. The throttle determines how much power the engine can develop by controlling the amount of fuel and air entering the engine cylinders. When fully open, the throttle allows the maximum amount of fuel and air to enter the system to produce maximum power. When the throttle is closed, only a small amount of fuel and air can enter the system, and the engine produces minimum power [2].

The reduction of air pollution from combustion devices is an increasingly serious concern worldwide due to the rise in fuel usage especially for transport applications in urban areas. Spark ignition (SI), widely used to power various types of vehicles, have been shown to be a major source of air pollution in cities. The primary pollutants emitted from modern SI engines are mainly oxides of nitrogen, (primarily nitric oxide, NO, with a small amount of nitrogen dioxide, $NO_2$, collectively known as $NO_x$), carbon monoxide (CO), organic compounds that are mainly unburned or partially burned hydrocarbons (HC), small

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amounts of oxides of sulfur and particulates [3]. In this study, the effect of different throttle opening on the performance of spark ignition (SI) engine and the emission for the fuel RON 95 was investigated. The study is concerning the terms of the power, speed and fuel consumption of the SI engine.

## 2 Approach and Methods

### 2.1 Experimental Design

The following experiment work was conducted to evaluate and examine the effect of variable throttle opening with constant or fixed engine speed on spark ignition engine fueled with RON 95. A Mitsubishi 12 valve, gasoline “spark ignition” type engine, connected to a hydraulic dynamometer (as shown in the Figure 1) and the engine fueled with “Ron 95”. The hydraulic dynamometer was used for the purpose of providing a variable load on the engine. The fuel was fed to engine while passing through flask to enable fuel consumption measurement. The variable throttle opening and engine speed was controlled by computer software. Exhaust emission such as carbon dioxide ($CO_2$), carbon monoxide(CO), unburned hydrocarbon (HC), as well as the excess oxygen ($O_2$) and air-fuel ratio were recorded and analyzed by a “KANE” gas analyzer.

*Figure 1: Photograph of Mitsubishi 12 Valve, 1.5L, MPI Engine.*

The instrument’s probe “KANE” was inserted into the exhaust flow as shown in the Figure 2. A pump located inside the device would draw a small amount of sample of the stack gas. A number of sensors in the “KANE” analyzed the contents of the stack gas, calculated and displayed the results. Electrochemical (SEM) sensors measured the carbon monoxide, carbon dioxide and oxygen.

### 2.2 Engine Specification

In this study, the experiment was performed on a Mitsubishi 1.5L (1500cc), 87 bhp, 4 cylinders, In-line MPI, and four-stroke gasoline engine. The engine specification is shown in the Table 1.

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*Figure 2: KANE Gas Analyzer*

*Table 1: Specification of Tested Engine*

| Mitsubishi 12 valve (SI) Engine Specification | |
|---|---|
| Engine Type | In-Line Engine |
| Engine Description | 1.5L 87bhp 4 cyl. In-line MPI |
| Engine Displacement(cc) | 1468 |
| No. of Cylinders | 4 |
| Maximum Power | 87PS, 63.988Kw@5,500 (rpm) |
| Maximum Torque | 13.5Kg-m, 132.4N-m@3,300 (rpm) |
| Valves Per Cylinder | 3 (2 intake, 1 exhaust) |
| Valve Configuration | SOHC |
| Fuel Supply System | MPFI |

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### 2.3 Fuel and Fuel Supply Measurement

In this study gasoline "RON 95" fuel was used. It is commercial grade gasoline that is specially formulated with advanced additive technology. It contains friction modifier to reduce internal friction between the cylinder and piston rings. As a result, better fuel economy is achieved. The fuel supply was passed through a flask (100 Ml capacity) before entering the intake manifold in order to measure the fuel consumption rate whereas the amount of fuel in the flask was controlled by a manual valve. The flask and valve are shown in Figure 3.

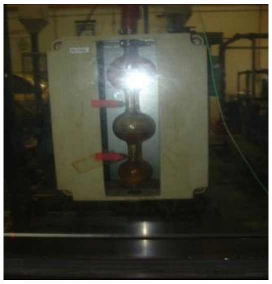

*Figure 3: Fuel Flasks and Valve*

### 2.4 Experimental Methods

The engine performance and emissions from fueling with "Ron 95" were evaluated at two fixed speed (4000 rpm and 4500 rpm) with a variable throttle opening 25%, 50%, 75% and 100%. For each fixed speed a series of experiments at variable throttle (which mentioned above) were carried out. The volumetric flow rate of fuel, power generated from engine and torque was measured. Based on the measurement, specific fuel consumption (sfc) was calculated. After the engine reached the stable working conditions, emission parameters such as CO, $CO_2$, HC, $O_2$, as well as the air-fuel ratio measured by the gas analyzer were recorded. Whenever the throttle opening changed the above procedure was carried out. The above mentioned procedures were repeated for each throttle opening level over the two fixed engine speeds 4000 rpm and 4500 rpm.

## 3 Results and Discussion

Figure 4 shows the torque output of the test engine using petrol RON 95 type under various throttle valve openings. It is included 2 types of engine speed. The data are taken at 4000 as well as 4500 rpm. It is seen that engine torque at 4000 rpm generated slightly higher at each engine speed than a fixed engine speed. While for the Figure 5 indicates that at engine speed 4500 rpm produced high engine power than 4000 rpm.

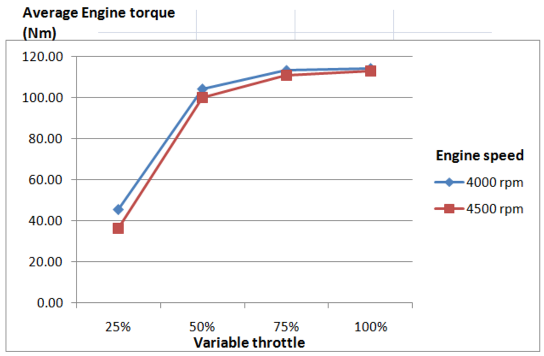


*Figure 4: Average engine torque (Nm) versus various throttle valve openings.*

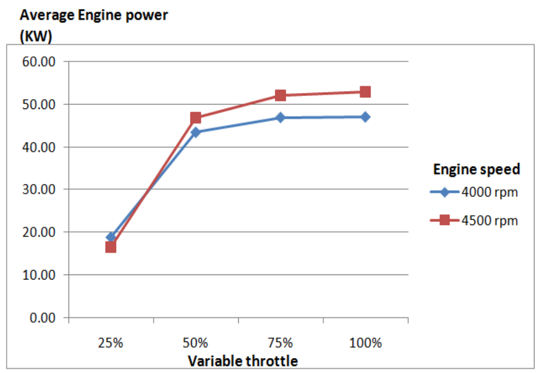


*Figure 5: Average engine power (kW) versus various throttle valve openings*

The duration of fuel usage has been recorded in Figure 6 to observe how many times have been used to finish off 100 ml for every each variable throttle. It is seen that at 25% of throttle opening during 4000 rpm has spent 45.28 seconds. This is in contrast for the same type of throttle opening just now during 4500 rpm where the time taken is 39.63 seconds. As can be seen, time taken is more quickly than other at 100% throttle opening during 4000 rpm, i.e. 17.6 seconds. While time for the 4500 rpm is 17.87 seconds. This condition occurred increasing the torque, need more fuel supply to the engine. While at engine speed of 4500 rpm can be considered that the engine speed has exceed the critical speed.

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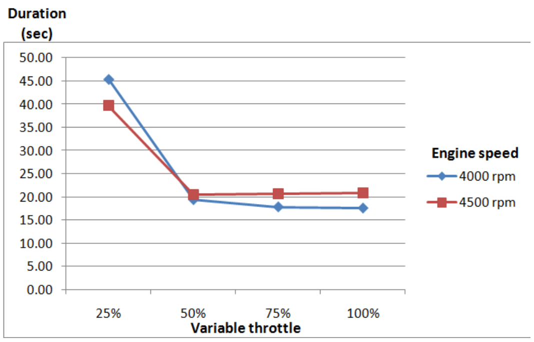


*Figure 6: Duration of fuel usage vs Variable throttle*

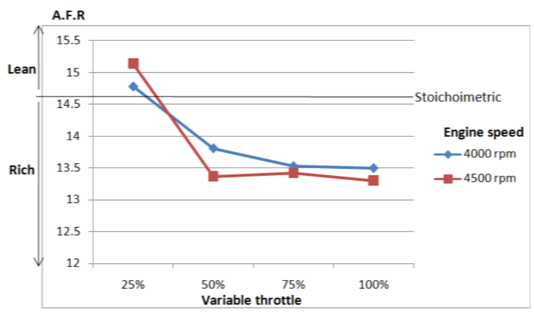


*Figure 7: Air fuel ratio versus various throttle completed 100 ml of RON95 fuel valve opening consumed versus various throttle valve openings*

From Figure 7, it is seen that almost the data obtained demonstrate in rich mixture or in other words is the value less than air fuel ratio 14.7 (stoichiometric). This occurred cause by injection duration which is high i.e. for increase the combustion in cylinder besides air induction which is high enter to the cylinder. On other word, to increase engine speed (rpm), it is need volumetric efficiency (V.E) which is high and so on result rich mixture.

The results of Figure 8 and Figure 9 show emission gases such as $O_2$, CO and $CO_2$ at engine speed 4000 rpm and 4500 rpm. It is seen that the number of CO% increase when the throttle opening increase for both engine speed. While the number of $CO_2$% at 4000 rpm is more than 4500 rpm. Although $CO_2$ is danger which could contribute to world global warming but the higher of $CO_2$% after combustion process in S.I engine isbetter and can prevent engine become overheat. For the $O_2$%, it indicates almost the value in between 0.16 – 1.00. It shows that only at throttle 25% at both speed respectively on 1.14% and 1.15%. The higher of $O_2$% will cause engine overheating.

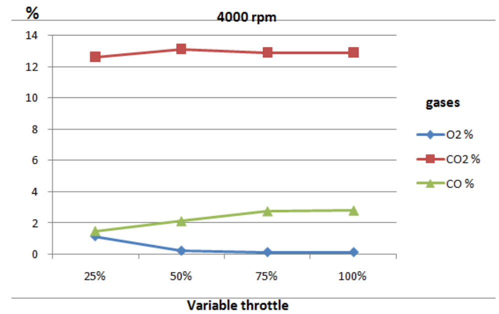


*Figure 8: Product of combustion percent at engine speed 4000 rpm versus various throttle valve openings.*

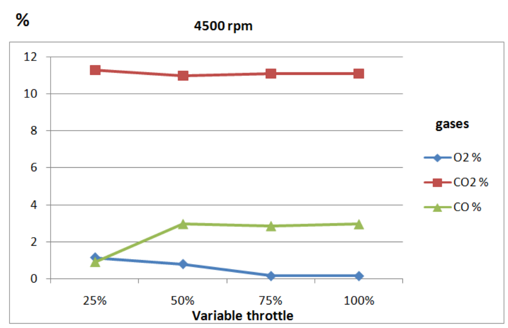


*Figure 9: Product of combustion percent at engine speed 4500 rpm versus throttle valve openings*

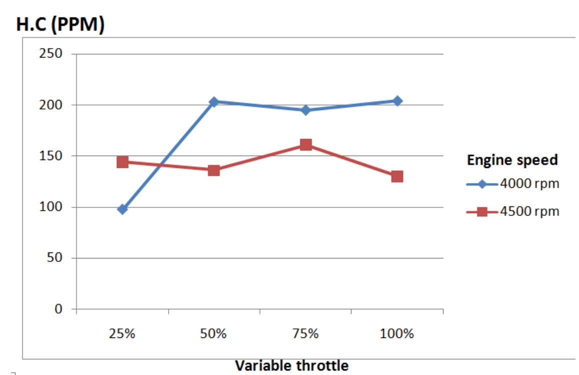


*Figure 10: Particles per million of hydrocarbon versus various throttle valve openings*

## 4 Conclusion

The effect of using gasoline (RON 95) on the performance of a Mitsubishi 12 valve, gasoline "spark ignition" engine

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such as performance, emission and fuel consumption against variable parameter such as engine speed and throttle variable was studied. It is found that at engine speed 4000 rpm at all condition of throttle opening is appropriate than at engine speed 4500 rpm although the different between both of speed is small. Engine speed at 4500 rpm will have better by using higher octane number such as RON 97.

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