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Effects of Air Intake Temperature on The Fuel Consumption and Exhaust Emissions of Natural Aspirated Gasoline Engine

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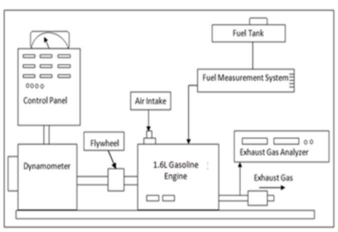
Graphical abstract



Abstract

Improving fuel consumption with lower exhaust emissions give more focused to all car manufactures. A higher engine performance with lower exhaust emissions requires a complete mixing process resulted in ultra-lean high combustion efficiency. Air intake temperature is one of the alternative strategies to improve fuel consumption and reduced exhaust emissions. This is due to the cold air is denser and contain higher oxygen availability. Air intake temperature will affect to the oxygen concentration in the charged air that influence the combustion process through ignition delay and fuel burning rate. The objective of this experiment is to investigate the effects of air intake temperature to the fuel consumption and exhaust emission at variation of engine speeds and constant load by using 1.6L gasoline engine. Air intake temperature was changed from 20 °C to 30 °C. The DaTAQ Pro V2 software was used to measure the engine fuel consumption while gas analyzer (MRU Gas Analyzer) was used to measure the exhaust emission such as Unburned hydrocarbons (UHCs) and carbon monoxide (CO). The results showed that fuel consumption, UHCs and CO emissions increased with the increase of air intake temperature. The increase of air intake temperature resulted in advanced and shorter combustion duration. Higher oxygen concentration at lower air intake temperature leads to the complete mixing process and complete combustion. Therefore, the experimental results can be concluded that the lower air intake temperature resulted in improved fuel consumption and reduced UHCs and CO emissions.

Keywords: Combustion engine, Unburned Hydrocarbon (UHC), high combustion efficiency, air intake temperature and Combustion stability

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1.0 INTRODUCTION

Improving fuel consumption with lower exhaust emissions give more focused to all car manufactures. A lower fuel consumption and reduced exhaust emissions requires a complete fuel air mixing process and ultra-high combustion efficiency. It is well accepted that the combustion and emissions characteristics are highly rely on the oxygen availability and fuel properties. The excess of oxygen resulted in very lean mixture that lead to the instable combustion and misfire [1]. In fact, lean mixture tends to promote a longer ignition delay and a slower burning rate resulted in longer combustion duration. This condition creates longer time for heat transfer from combustion to the end gas that lead to the knocking phenomenon. However, the engine operates with deficiency of oxygen resulted in rich mixture that leads to the higher unburned gaseous fuel due to shorter ignition delay and faster burning rate. Therefore, it is vital to make sure the charged air entered into the combustion chamber was sufficient of oxygen in order to promote complete combustion. The previous researches also showed that the air intake temperature has a significant role to increase the combustion efficiency, stability and reduced exhaust emissions [2-5].

Based on previous study, fuel economy can be improved through several strategies such as introduce electronic devices into the gasoline engine [6]. In general, lower fuel consumption and less emission can be achieve by having complete combustion in the combustion chamber. The increased oxygen availability in the combustion chamber can promotes complete combustion and oxidation of both CO and HC emissions. Controlled air intake temperature is one of the possible methods to promote higher combustion efficiency and improved combustion stability. Air intake temperature is important to ensure higher amount of fuel involves in the combustion process. Besides that, air intake temperature will also control the exhaust emissions and combustion process. The emissions and combustion quality is controlled through a complete mixing process between fuel-air.

The improved combustion process leads to an increased engine specific power, better fuel consumption, higher thermal efficiency and reduced harmful emissions. The objective of this study is to investigate the effect of air intake temperature on fuel consumption and emission by using a 1.6L natural aspirated spark ignition engine.

2.0 EXPERIMENTAL SETUP AND PROCEDURE

The experiments were carried out on a multi-cylinder 4 stroke 1.6L gasoline engine. The detail description of engine specification is shown in Table 1. A variation of air intake temperatures was created through a combination of air conditioning and cooling tower unit. The conditioned air is supplied to the engine through original air intake system.

Table 1 Engine specification

Power train Engine & Performance	
Engine	4 Cylinder, DOHC 16V
Maximum Speed (km/h)	190
Acceleration 0– 100km/h(sec)	10.5
Fuel	Gasoline
Full Tank Capacity (Liter)	50
Injection Type	Fuel system multi-point injection (MPI)
Number of Cylinder & Configuration	4 (in-line)
Displacement (cm^3)	1597
Bore (mm)	76
Stroke (mm)	88
Compression Ratio	10:1
Maximum Power (kW/RPM)	6,500 @ 125 HP (93 HP)
Maximum Torque(Nm/RPM)	4,500 @ 150 Nm

The engine test bench was mainly consists of a dynamometer and controller, data recording and exhaust analysis system. Figure 1 show the detail schematic diagram of the engine setup and instrumentation. The tests were carried out at variation of engine speeds and constant load of 60 Nm.

Table 2 Fuel properties

Fuel Properties	Value
Researches Octane Number (RON)	95
Density	750 kg/m^3
Viscosity	5x10^{-6} m^2/s
High Heating Value [HHV]	45.7 MJ/kg
Lower Heating Value [LHV]	42.9 MJ/kg
Theoretical Air Fuel Ratio [AFR]	14.5

All the tests were performed with gasoline RON 95 and the fuel properties are given in Table 2. The exhaust gas of the engine is passed through the gas analyzer via sample line and two gases UHCs and CO are measured. The exhaust sample acquisition time is approximately 10 seconds in an operating environment temperature is 33 to 36 deg C and the relative humidity is approximately 60-70 percent. The DaTAQ Pro V2 software was used to measure the fuel consumption while gas analyzer (MRU Gas Analyzer) was used to measure the exhaust emission such as Unburned hydrocarbon (UHC) and Carbon Monoxide (CO).

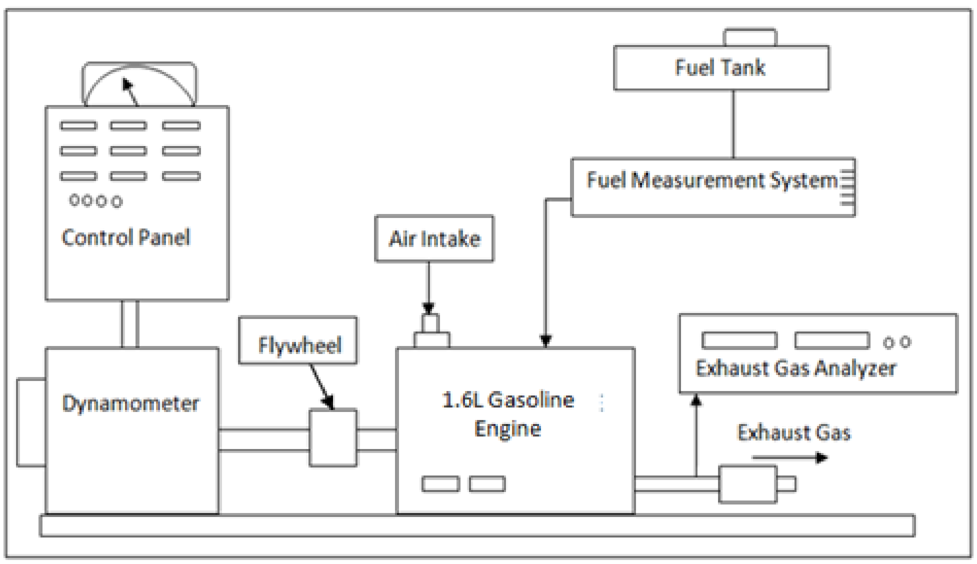

Figure 1 Schematic diagram of engine set up

3.0 RESULTS AND DISCUSSION

3.1 Brake Specific Fuel Consumption (BSFC)

Figure 2 shows the result of BSFC when the engine operating at 1500 rpm until 3000 rpm with a variation of air intake temperatures (20°C, 25°C and 30°C). In all engine test conditions the BSFC decreases as the engine speed increases due to air turbulent effects resulted in an improved fuel mixture and complete combustion. At higher engine speed, a larger portion of gaseous fuel to be involved in the oxidation process that leads to higher reaction activity resulted in lower BSFC. The results also show that the BSFC decreases as the air intake temperature decreases.

The ignition delay period is reduced with lower air intake temperature due to higher oxygen availability. This allows combustion occurs at the end of compression stroke and early of expansion stroke which convert larger fraction of the fuel energy to the useful work. The results show that the effect of air intake temperature is dominant at higher engine speed compared with lower engine speed. This is due to higher injected fuel at higher engine speed that requires more oxygen to complete the combustion [3].

The highest value of brake specific fuel consumption was 380 g/kW.hr at higher air intake temperature 30°C, which was 4 % higher than the lowest air intake temperature 20°C at the same engine speed of 1500 rpm. But, when the engine speed increase up to 3000 rpm, the value of BSFC reduce about 22 % from 380 g/kW.hr to 298 g/kW.hr. The higher air intake temperature resulted in lower oxygen concentration will lead to a small negative effect on the combustion rate and BSFC [7].

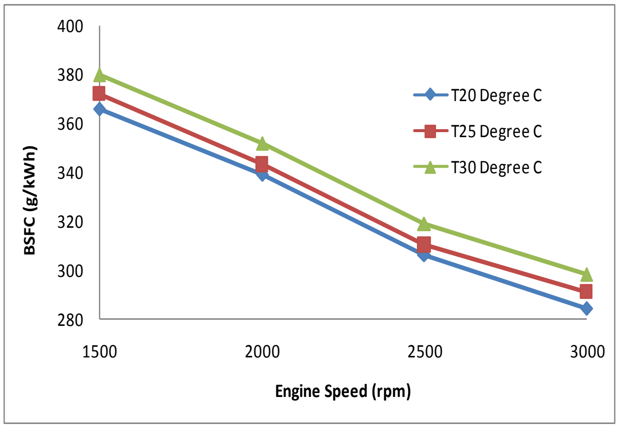

Figure 2 BSFC with variation air intake temperature at various of engine speeds and constant engine load

3.2 Carbon Monoxide (CO) Emission

Figure 3 illustrates the carbon monoxide emissions of the engine operating at different engine speed and constant engine load. In fact, CO emissions are greatly influenced by fuel–air mixing and the air-fuel ratio [4]. It is observed that the concentrations of carbon monoxide keep increase directly proportional due to increase of engine speed. The engine speed was set-up from 1500 rpm to 3000 rpm. The result shows that 341 ppm of CO emissions was produced when the engine operates with 20°C of air intake temperature at 3000 rpm of engine speed. The value was 6 % lower than the engine operates at 30°C of air intake temperature. The behavior of CO emission is consistent with the quality of the combustion process and poor oxidation of mixture. The higher air intake temperature tends to reduce oxygen availability resulted in an unstable combustion where partial burn and misfire may take place.

It also was found that, the emissions of CO decreased with the decrease of air intake temperature regardless of engine speed. The possible reason is due to higher oxygen availability at lower temperature resulted in complete fuel mixing process and complete combustion.

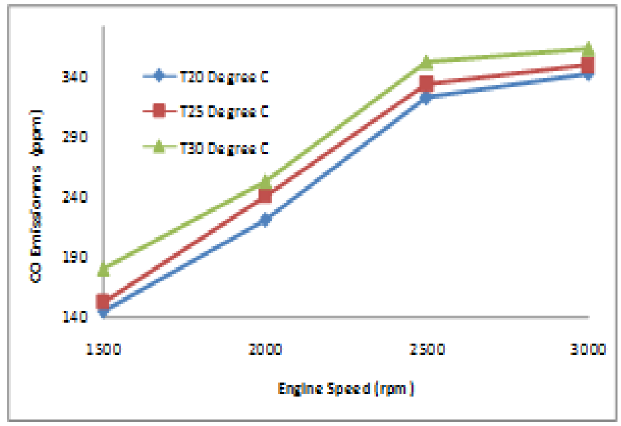

Figure 3 CO Emission with variation air intake temperature at various of engine speeds with constant engine load

3.2 Unburned Hydrocarbons (UHCs) Emission

Figure 4 shows the UHCs emissions trend for a gasoline engine operating with different engine speeds and constant engine load at variation of air intake temperatures. Ideally, the fuel should be evaporated and mix with air before initiates the combustion process. The mixing process is highly dependent on the fuel droplet size, heat and oxygen availability [8]. The trend of UHCs emissions was similar to that observed in previous results of CO emissions. The UHCs emission level was increased with the increase of the engine speed is due to high amount of fuel involved during the combustion process. However, the UHCs emissions decreased with the decrease of air intake temperature. This is due to high combustion temperature caused by pre-mixed burning and high rate of oxidation of UHCs at lower air intake temperature [9]. The lower air intake temperature is also possible to ignite combustion at rich region mixture [10].The higher UHCs emissions are produced by the engine operating at 30°C of air intake temperature is due to poor mixing process and incomplete combustion. The behavior of UHCs emission is consistent with the amount of unburned gaseous fuel in the exhaust gas. This value is 128 ppm which is 10 % higher than the engine operates with 20°C of air intake temperature at the same engine test condition. The UHCs emissions at high engine speed 3000 rpm was higher about 85 % than at lower engine speed 1500 rpm for all variation of air intake temperature because of influence by the reducing of oxygen concentration that supplied to combustion chamber and high amount of injected fuel.

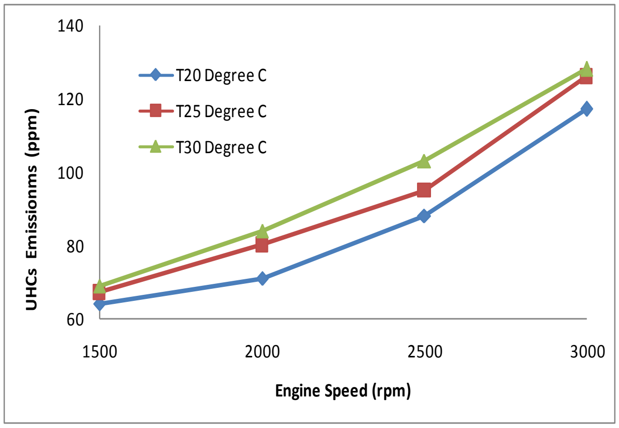

Figure 4 UHCs Emission with variation air intake temperature at various of engine speeds with constant engine load

UHCs emissions are generally produced due to incomplete combustion of a carbon containing fuel. Lower excess oxygen concentration results in rich air–fuel mixtures at different locations inside the combustion chamber [11]. This heterogeneous mixture does not combust completely and results in higher UHCs emissions. In addition, the longer ignition delay due to the oxygen deficiency caused by increased air intake temperature will lead to poor UHCs oxidation process.

4.0 CONCLUSION

Experimental work was carried out to study the effects of air intake temperature on fuel consumption and exhaust emission of a multi cylinder 1.6L gasoline engine. The tests were performed at variation of engine speed and a constant engine load with different air intake temperature (20°C, 25°C and 30°C). The results showed that the fuel consumption is improved with the decrease of air intake temperature regardless of engine speed. The lowest value of brake specific fuel consumption was occurred at air intake temperature of 20°C. For the emission analysis, carbon monoxide and unburned hydrocarbons were decreased with the decrease of air intake temperature regardless of engine speed. Combustion process at lower air intake temperature has remarkable results than compared with higher air intake temperature due to higher oxygen concentration. In conclusion, the lower air intake temperatures resulted in lowest fuel consumption and reduced exhaust emissions regardless of engine speed.

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References

[1] Mohsen M. Abdelaal, Basem A. Rabee, Abdelrahman H. Hegab. 2013. Effect of Adding Oxygen to the Intake Air on a Dualf Engine Performance, Emissions, and Knock Tendency. *Journal of Energy*. 61: 612-620.

[2] Mamat, R., Abdullah, N. R., Xu, H. M., Wyszynski, M. L. & Tsolakis, A. 2009. Effect of Fuel Temperature on Combustion and Emissions of a Common Rail Diesel Engine. *SAE International Powertrains, Fuels and Lubricants*. 2009-01-1896.

[3] Rizalman Mamat, Ahmad Fitri Yusop, Abdul Adam Abdullah, Amir Aziz, Nik Rosli Abdullah. 2013. Effect of EGR and Air Temperature on Exhaust Emission of a Diesel Engine Operating with Biodiesel, *Journal of Biobased Materials and Bioenergy*. 7: 461-463.

[4] Nik Rosli Abdullah, Nafis Syabil Shahruddin, Rizalman Mamat, Aman Mohd. Ihsan Mamat & Aminuddin Zulkifli. 2013. Effects of Air Intake Pressure on the Engine Performance, Fuel Economy and Exhaust Emissions of a Small Gasoline Engine. *Procedia Engineering*. 68: 278-284.

[5] Takagi, Y.1996. The Role of Mixture Formation in Improving Fuel Economy and Reducing Emissions of Automotive S.I. Engines. *FISITA Technical Paper*. No. P0109.

[6] K. Callaghan & S. Nemser. 1999. Oxygen Enriching Membranes for Reduced Cold Start Emission. *SAE Paper* 1999-10-1232.

[7] Zehra Sahin, Mustafa Tuti, Orhan Durgun. 2014. Experimental Investigation of the Effects of Water Adding to the Intake Air on the Engine Performance and Exhaust Emissions in a DI Automotive Diesel Engine. *Journal of Fuel*. 115: 884-895.

[8] Cinar, C., Uyumaz, A., Solmaz, H., Sahin, F., Polat, S. & Yilmaz, E. 2015. Effects of Intake Temperature on Combustion, Performance and Emission Characteristics of A HCCI Engine Fueled with the Blends of 20% n-heptane and 80% Isooctane Fuels. *Fuel Processing Technology*. 130: 275-281.

[9] Cinar, C., Uyumaz, A., Solmaz, H., Sahin, F., Polat, S. & Yilmaz, E. 2015. Effects of Intake Air Temperature on Combustion, Performance and Emission Characteristics of a HCCI Engine Fueled with the Blends of 20% N-Heptane and 80% Isooctane Fuels. *Journal of Fuel Processing Technology*. 130: 275-281.

[10] Rakesh Kumar Maurya & Avinash Kumar Agarwal. 2011. Experimental Investigation on the Effect of Intake Air Temperature and Air–fuel Ratio on Cycle-to-Cycle Variations of HCCI Combustion and Performance Parameters. *Journal of Applied Energy*. 88: 1153-1163.

[11] Ramzi, H. A., Ibraheem Al-Barwari, R. & Talabany, Z. J. 2013. Effect of Ambient Air Temperature on Specific Fuel Consumption of Naturally Aspirated Diesel Engine. *Journal of Science and Engineering*. 1: 1-7.