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Effect of Changing in Air Intake Temperature on Engine Performance Using Thermocouple

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Abstract: The effect of changing in air intake temperature plays an important role to the performance of spark ignition engine. Therefore, increasing or decreasing of surrounding temperature in the world nowadays will affect the performance and the quality of air especially related to spark ignition engine. Thus, this study will be conducted to determine the heated value of air intake temperature that influence engine performance and emission. Spark ignition engine also known as heat engine depends so much to the changes in temperature. This study will present the experimental result on the performance of spark ignition engine at various cooled air intake temperatures on four-stroke four-cylinder spark ignition engine. This study also investigated the level of emission released to the environment due to decrease in air intake temperature. In this study, the exhaust emissions percentage values of CO_2 and HC are recorded by using Chassis Dynamometer (MD-2WD-500). The data was taken under three different gears (gear 2, 3 and 4) at varying speed (1000, 1500, 2000, 2500 and 3000 rpm) and intake temperature range (15℃~25℃). Based on the data and result recorded, decrease in temperature do increase the engine performance and also decrease the emission percentage as well.

Keywords: Chassis dynamometer (MD-2WD-500), spark ignition engine

1. Introduction

The air intake system is critical to the function of the engine, collecting air and directing it to cylinders. Since the air intake system is a part of engine, first must understand the engine in order to visualize how air intake system works. Basically, most of the engine converts thermal energy into mechanical energy and they are known as heat engine. Heat engine classified in two categories; one of them is internal combustion engine and the other is external combustion engine such as steam engine. Internal combustion engine refers to the combustion occur in the closed chamber between fuel and air that mix together with concern of high temperature and high pressure involve [1]. The air needed to mix with the fuel is supplied by the air intake system. Oxygen in the air is one of the necessary ingredients for the engine combustion process.

A good air intake system allows for clean and continuous air flow into the engine, thereby achieving more power and better mileage for the car. The air intake system consists of the air filter, throttle body and the mass flow sensor. Engine performance is one of the major concerns for the users, designers and the manufacturers of internal combustion engine nowadays. The designers always interested in method to improve the performance of the engine without increasing the cost by altering the compression ratio or air-fuel mixture [2].

The most economically way is by manipulating the temperature or heat factors. One of the potential experimental change that can be done is by manipulating the air intake temperature. As a whole in this study, an attempt has been made to experimentally investigate the suitable air intake temperature for the emission. The emission testing parameters are hydrocarbon percentage and carbon dioxide percentage of the tested vehicle which is the Myvi 1.3L G manual with

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3 different gears with varying speed (1000, 1500, 2000, 2500 and 3000 rpm) and intake temperatures (15℃~25℃). The result will contribute to the future car designers to set the default temperature without depending on the ambient temperature.

1.1 Literature Review

First theory of internal combustion engine was established in late sixteenth century; however, the theory was relinquished because of the steam control motor begin to demonstrate a great deal of guarantee by the development of steam power engine. In 1876 Nicklaus August Otto showed the true principal 4-stroke cycle and it ended up known as Otto Cycle [3]. Internal Combustion Engines (ICE) manufacture mechanical power from the energy contained within the fuel, as a result of the combustion method occurred within the ICE. The high-pressure gases then expand and push the piston to a mechanical mechanism to rotate the rotating shaft. The rotating shaft reacted as an output of the engine, connected to a transmission or gear train to transmit the energy to drive a vehicle (see Fig. 1).

The Spark Ignition engine is quite a straightforward product and that is why it's a lower initial price. The matter with spark ignition engine is its poor half load potency by examination to full load potency because of giant loss throughout gas exchange impact by low combustion and low physics potency. There are many findings concerning the relation of close temperature or intake temperature to the performance of engine, expressing that the usage of spark ignition engine, the effect increasing the intake temperature has a bonus of reducing exhaust emission, however high head temperature will increase thermal stress within the top of piston crown that will increase the tendency to knock, pre ignition and reduces meter potency [4].

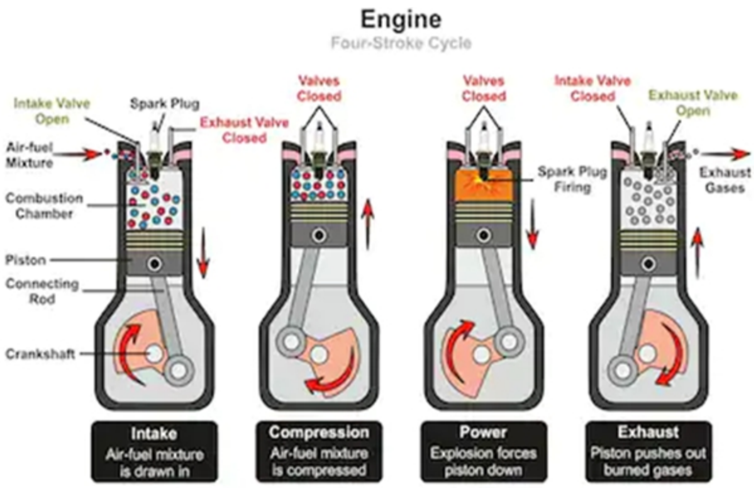

Fig. 1 - The working principle of SI Engine [5]

Combustion, also known as burning, is the basic chemical process of releasing energy from a fuel and air mixture. In an internal combustion engine (ICE), the ignition and combustion of the fuel occurs within the engine itself. The engine then partially converts the energy from the combustion to work. The engine consists of a fixed cylinder and a moving piston. Complete combustion or simply renowned is to properly expend all the gasoline and not have any leftovers. In complete combustion, the fuels or chemical utterly burning and solely manufacture greenhouse emission and water. There must be enough offered chemical element for each atom within the compound to seek out a match or a combine within the environmental air. The organic compound burns in conjunction with atmosphere chemical element, O_2 and created water and greenhouse emission, CO_2.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O \qquad (1)$$

If there is not enough oxygen present to completely burn the fuel to carbon dioxide and water, it is called in complete combustion. Incomplete combustion can cause pollution and fuel inefficiency. Usually in complete combustion produce less heat than complete combustion. According to previous study, incomplete combustion is due to improper mixing and flame quenching. Improper mixing is incomplete mixing of air and fuel when some particle of fuel does not find molecule of oxygen to burn [6].

$$4CH_4 + 7O_2 \rightarrow 2CO + 2CO_2 + 8H_2O \qquad (2)$$

Engine power or power unit is that the most power that associate degree engine will place out. It is often expressed in kilowatts or power unit. The ability output depends on the dimensions and style of the engine, however additionally on the speed at that it's running and the load or force. Most power is achieved at comparatively high speeds and at high load. Power is the amount of work done per specific time or the rate of doing work. The measure of the engine's ability to apply power generations called torque. Engine torque is normally measured by a dynamometer. Brake power refers to the amount of usable power delivered by the engine to the crankshaft [7]. Brake Power also refers to the measurement output of the engine. This power from the engine drive shaft is measured by a dynamometer also known as brake. The engine is connected to a brake or dynamometer, which can be loaded in such a way that the torque exerted by the engine can be measured.

$$Brake\ power, BP = 2IINT \tag{3}$$

Emissions from internal combustion engine are one of major concern to world today because of their negative impact on air quality, human health, and global warming. Therefore, there is an integrated effort by most governments to control them. Emissions from combustion include unburned hydrocarbons (HC) and carbon monoxide [8]. Each of the emissions as the result of typical combustion have their own level of toxicity and, when combined with other elements such as water droplets in the atmosphere, can create hazardous pollution scenarios. Each element of exhaust emissions carries its own properties, which can become significant problems when large groups of vehicles are constantly traveling the same roads day in and day out [8]. These exhaust gasses are the gaseous emitted as a result of the combustion of fuels such as natural gas, gasoline, petrol, biodiesel blends, diesel fuel, fuel oil, or coal. According to the type of engine, it is discharged into the atmosphere through an exhaust pipe, flue gas stack, or propelling nozzle.

During combustion, the carbon (C) from the fuel combines with oxygen (O_2) from the air to produce carbon dioxide (CO_2) In the presence of oxygen, including atmospheric concentrations, carbon monoxide burns with a blue flame, producing carbon dioxide. The oxidation rate of CO_2 limited by reaction of the kinetics and therefore, can be accelerated only to a certain extent by improvements in air and fuel mixing during the combustion process. The hydrocarbons are thus mainly particles of unburned and partly burned original fuel. Lubrication oil also contributes to the emission of hydrocarbons. Hydrocarbon emissions can be a variety of different configurations with different contents of for example H, C, N, S and O and in different sizes from methane (CH_4) to longer hydrocarbon chains.

Any engine that runs by internal combustion of fuel needs air to operate (see Fig. 2). The air intake system is critical to the function of the engine, collecting air and directing it to individual cylinders, but that’s not all. That's because without air especially oxygen, fuels cannot burn and provide the combustion that force to power the engine. In modern automobiles, the air must be cleaned before introduced the inlet manifold and combustion chamber. In addition, modern engines rely on a precise ratio of air to fuel. When the engine is starved of air, the fuel mix is said to run too rich, which in effect the performance of the engine. The air supplied to the engine through inlet manifold [9].

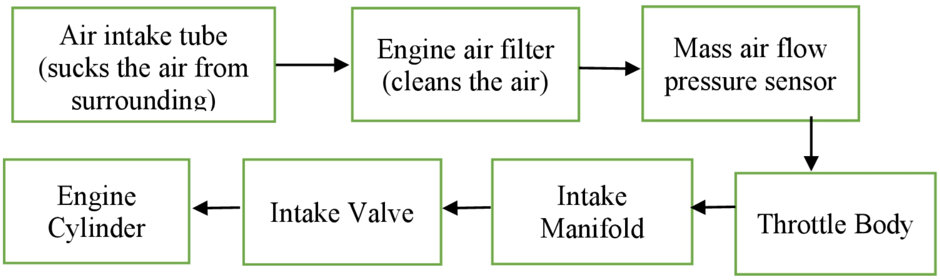

Fig. 2 - Block Diagram of the air intake system [7]

2. Materials and Methodology

2.1 Materials

The materials needed and used in this project mostly are used in automotive lab where emission testing is done using emission analyzer (Bosch 060 and 070). The whole testing is made by using 1.3L 4-stroke Myvi engine and undergoes emission testing (hydrocarbon and carbon monoxide). The manipulating variables in the test are the RPM, air intake temperature and the gear (Gear 2, 3 and 4). For the air intake temperature, a cooler is set up on the air intake system with Thermocouple and Digital temperature controller (DTC) to vary the air intake temperature according to the preferred condition. The cooling system consist of relay, 15-amp fuse and a CPU fan.

i. Emission testing tools:
   - Emission analyzer (Bosch 060 and 070)
   - Chassis Dynamometer (MD-2WD-500)
   - Spark ignition engine
ii. Cooling system:
   - Air intake system
   - CPU fan
   - Air inlets
   - Microwave airtight container
   - Ice cubes
iii. Electrical components
   - Thermocouple - To detect the temperature inside air intake system
   - Digital Temperature Controller (DTC) - To vary air intake temperature according to the preferred condition.
   - 12V Battery - To provide current for Digital Temperature Controller and CPU fan.
   - Fuse 15 amp - To provide overcurrent protection.
   - Relay - Simple switches which are operated both electrically and mechanically.
   - Alligator car battery clips - To connect the wires.

2.1 Experimental Setup for Emission Testing

Setup the car on dynamometer and the ratchet strap harness is fixed so that the vehicle is hold onto the position (see Fig. 3). Once the strap harness is fixed and checked, the tachometer is fixed to detect the engine speed when the car is running. The modified air intake system is installed substituting the old one. Once the cooling system is all setup, the On-Board Diagnosis (OBD) device are plugged in with cable that connected with car's ECU. The Bluetooth connection between the OBD and the computer is established. The Bosch Emission Analysis (BEA) software is run on the computer. The manipulating variables in the test are RPM, air intake temperature and the gear (Gear 2, 3 and 4). The Hydrocarbon percentage and carbon dioxide percentage is taken with the cooling system and without the cooling system.

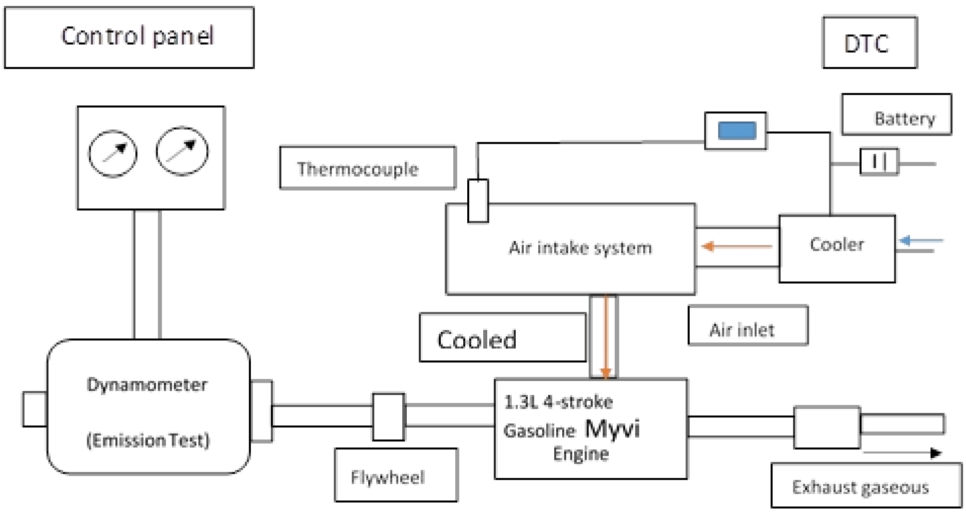

Fig. 3 - The schematic diagram for experimental setup

3. Results and Discussions

This part will discuss and analyze result of the experiment that have been conducted to obtain the data of emission of the 4-stroke engine. The test is to investigate and compare the data obtained before and after the installation of the cooler in terms of emission (hydrocarbon and carbon dioxide).

3.1 Hydrocarbon Percentage Value

In gear 2, the hydrocarbon value decreases with the presence of cooler compared to the hydrocarbon value without the presence of cooler as tabulated in Table 1. This is because the cooled air leads to partial combustion and this decrease the hydrocarbon level as the engine piston works at its usual speed but at cooled air intake temperature decreasing it combustion efficiency. The highest hydrocarbon value with cooler recorded was 10.10% at 3000rpm and the lowest was 6.23% at 1000rpm.

Table 1 - The gear 2 - hydrocarbon percentage value (%)

Gear 2	Rpm	1000	1500	2000	2500	3000
Hydrocarbon (%)	Cooler	6.23	7.2	7.98	8.98	10.1
	Without cooler	10.3	11.2	11.3	11.1	11.2

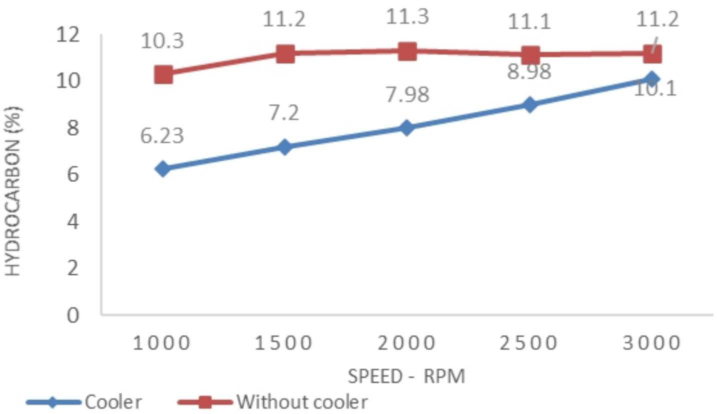

Fig. 4 - Bar graph of gear 2 hydrocarbon percentage value (%) against speed (rpm)

While for the hydrocarbon level without cooler the highest value was 11.20% and the lowest was 10.30%. For gear 3 the highest hydrocarbon value with cooler recorded was 10.08% at 3000rpm and the lowest was 6.77% at 1000rpm (see Table 2 and Fig. 5). While for the hydrocarbon level without cooler the highest value was 19.21% and the lowest was 7.70%.

Table 2 - The gear 3 - hydrocarbon percentage value (%)

Gear 2	Rpm	1000	1500	2000	2500	3000
Hydrocarbon (%)	Cooler	6.77	7.3	8.22	9.12	10.08
	Without cooler	7.7	13.1	15.42	17.92	19.21

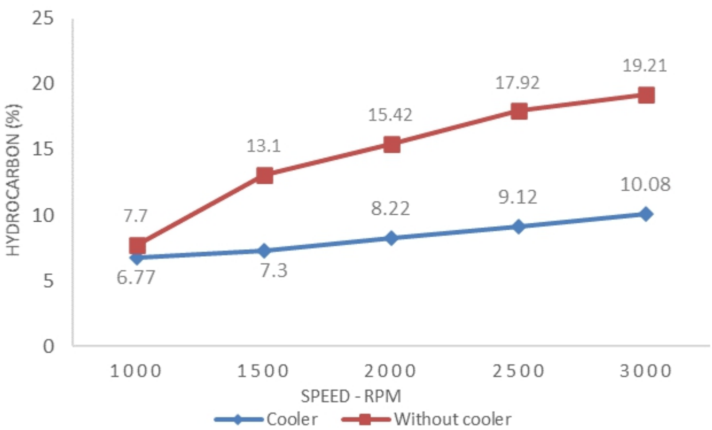

Fig. 5 - Bar graph of gear 3 hydrocarbon percentage value (%) against speed (rpm)

The gear 4 value recorded shows, the best possible hydrocarbon value with heater recorded was 10.10% at 3000rpm and the lowest used to be 6.23% at 1000rpm. While for the hydrocarbon level without heater the highest value was 10.90% and the lowest was 7.60% (see Table 3 and Fig. 6).

Table 3 - The gear 4 - hydrocarbon percentage value (%)

Gear 2	Rpm	1000	1500	2000	2500	3000
Hydrocarbon (%)	Cooler	6.23	7.43	8.34	9.12	10.1
	Without cooler	7.6	9.2	9.4	10.9	10.9

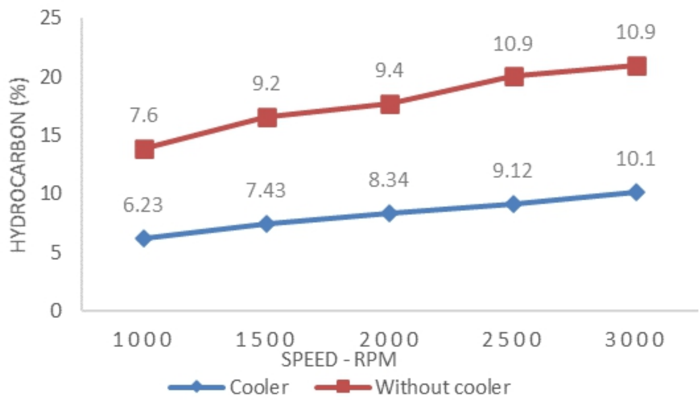

Fig. 6 - Bar graph of gear 4 hydrocarbon percentage value (%) against speed (rpm)

3.2 Carbon Dioxide Percentage Value

For the gear 2, higher engine speed and cooled air intake temperature because lower combustion rate that subsequently will produce less carbon dioxide. The highest carbon dioxide with cooler recorded was 10.21% at 3000rpm and the lowest was 6.02% at 1000rpm. While for the carbon dioxide level without cooler the highest value recorded was 11.55% and the lowest was 8.76% (see Table 4 and Fig. 7).

Table 4 - The gear 2 carbon dioxide percentage value (%)

Gear 2	Rpm	1000	1500	2000	2500	3000
Carbon dioxide (%)	Cooler	6.02	7.89	8.88	9.11	10.21
	Without cooler	8.76	10.82	11.31	11.48	11.55

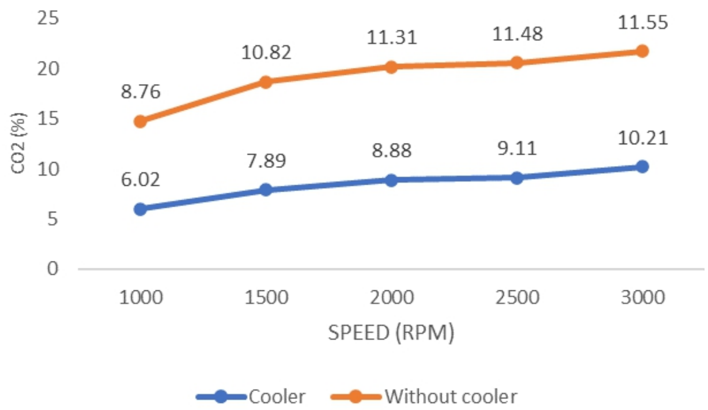

Fig. 7 - Bar graph of gear 2 carbon dioxide percentage value (%) against speed (rpm)

Meanwhile in gear 3, the carbon dioxide value reaches the value 9.88% at 2000rpm and lowest value 7.23% at 1500rpm. For the value without the cooler, the highest value obtained was 11.2% at 1000rpm and the lowest value was

11.03% at 1500rpm. The increasing gear (load) influences the percentage value of the carbon dioxide (see Table 5 and Fig. 8)

Table 5 - The gear 3 carbon dioxide percentage value (%)

Gear 3	Rpm	1000	1500	2000	2500	3000
Carbon dioxide (%)	Cooler	7.44	7.23	9.88	10.56	10.88
	Without cooler	11.3	11.2	10.9	11	11

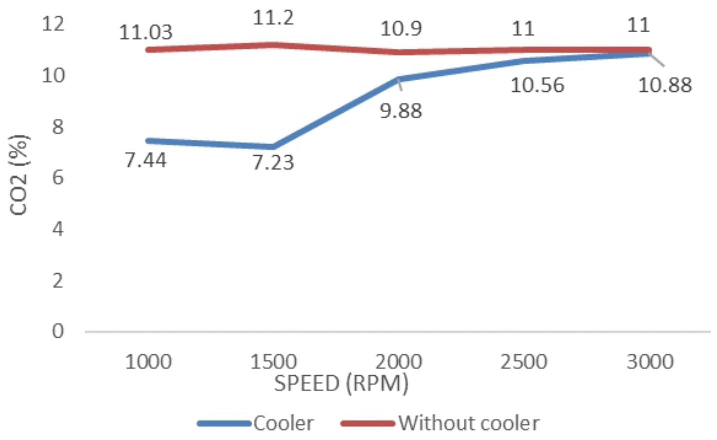

Fig. 8 - Bar graph of gear 3 carbon dioxide percentage value (%) against speed (rpm)

The final gear, gear 4 recorded its peak value which is 10.98% at 3000rpm (see Table 6 and Fig. 9). At the initial stage 1000rpm, the carbon dioxide degree recorded lowest in both conditions which was 7.02% with cooler and 11.33% without cooler.

Table 6 - The gear 4 carbon dioxide percentage value (%)

Gear 4	Rpm	1000	1500	2000	2500	3000
Carbon dioxide (%)	Cooler	7.02	7.88	8.98	9.12	10.98
	Without cooler	11.33	11.76	11.83	11.7	11.68

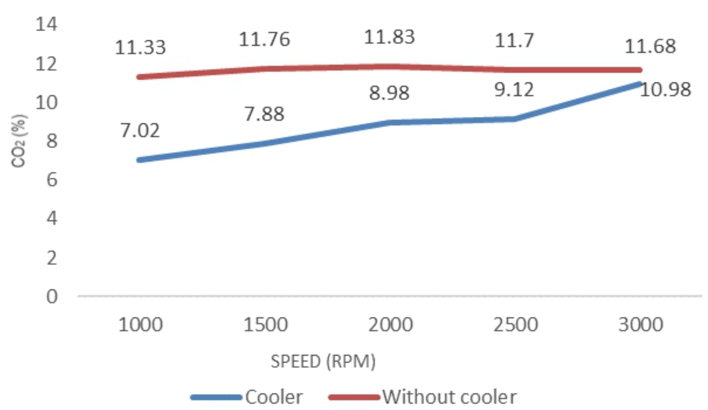

Fig. 8 - Bar graph of gear 4 carbon dioxide percentage value (%) against speed (rpm)

4. Conclusion

This experiment was conducted by designing a cooling system that cools the air lower than the ambient temperature. The data for this experiment was collected in term of emission level by conducting test on dynometer test machine. For the emission test, hydrocarbon percentage value and carbon dioxide percentage value were recorded under different gears (gear 2, 3 and 4), speed (1000, 1500, 2000, 2500 and 3000) and different conditions which was without cooler and with cooler. The results obtained shows that decreasing air intake temperature has the ability to decrease the percentage level of hydrocarbon and carbon dioxide at the exhaust emission that can pollute the nature.

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