Influence of Intake Air Temperature on Performance of Small Gasoline Engine

Tawarat Treeamnuk, Suranaree University of Technology, Thailand
Krawee Treeamnuk, Suranaree University of Technology, Thailand
Sakkarin Papakae, Suranaree University of Technology, Thailand

The Asian Conference on Sustainability, Energy & the Environment 2018
Official Conference Proceedings

Abstract
This research study was to investigate the influence of intake air temperature on the performance of a multi-propose small gasoline engine. The four-strokes gasoline engine with single-cylinder of 208 cm^3 was tested at speed of 1,500-4,000 RPM. The intake air temperature was prepared in case of 1) warm temperature that was like the air around the engine at 50^{o}C - 55^{o}C and room humidity 2) low temperature, warm air was cooled by using evaporative cooling pad system (ECP) with the room temperature water and 3) very low temperature, warm air was cooled by using the ECP system with 0.5^{o}C of cool water. The engine performance was tested on the water break dynamometer to determine torque, speed, fuel consumption, air induction rate. The result shown that the reducing air temperature before taking into the engine by ECP system influences on the increasing of density, relative humidity and pressure of the intake air. The low temperature of intake air provides an engine torque and power increasing. The power increases 3.21% at 2,000 RPM of engine speed (use room temperature water) and 7.76% at 3,500 RPM (use cool water) and the specific fuel consumption reduces 7.04% at 3,500 RPM. The exhaust temperature and HC emissions are decreased when compare to the warm intake air.

Keywords: Evaporative cooling, Intake air temperature, Engine testing, Engine performance

Introduction

Small multi propose gasoline engine is a world wild favor useful engine. Because this engine is not expensive, easy to control the speed, installation, power transmission, and have an accuracy control system. In Thailand, small multi propose engines are used in water pump, electricity generator, power for agricultural machinery such as two wheels tractor, mowers, fertilizer and chemicals sprayer, chopper machine and tools for cultivation, etc. Although this engine is highly popular, but it has a problem in operation because it cannot provide the high theoretical performance in practical applications. Especially the stationary engine, the air around the engine accumulates heat from the engine cooling system and changes to be the warm air at 50^{o}C - 55^{o}C due to the engine is running. At this temperature, the air is low pressure than cool air and has low density too. Unavoidably, this warm air will be taking into the engine and effects the engine thermal efficiency to low value in finally. Therefore, the reducing of intake air temperature is important and can directly improves the engine performance without difficultly modify the engine components. The reducing of air temperature by water evaporative cooling is a simple method. Using free water surface on the wet porous pad (or Evaporative air-water cooling pad system, ECP) (Fig. 1), the warm air can flow pass and lose its heat to the water. At the same time, the heat that water was received in form of latent heat change the liquid phase of water to be a gas phase. After that, it mixed within the air and flow out from the system. So, this method must increase the humidity of air ever (Papakae *et al.*, 2017). At present, the ECP was most applied in an air conditioning system. Because it is a simple system, not complicated equipment, designed to be a compact and more ability to reduce air temperature down 15^{o}C from room temperature. The low temperature air by this technique can increase 10.6% of overall air conditioning efficiency and decrease 11.4% of compressor power consumption (Martínez *et al*., 2016).

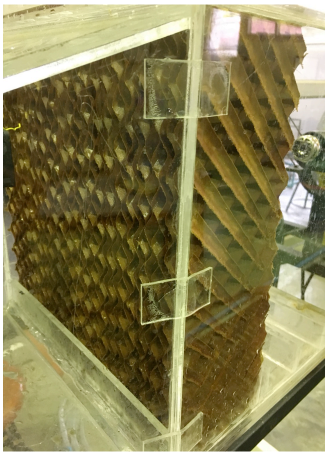

Figure 1: Evaporative cooling pad.

Many researchers are interested to study about the effect of air temperature on the engine operation. Sajovaara *et al*. (2015) reported that the reducing of air temperature before inducting to the engine can reduce the NOx emission and exhaust temperature of diesel engine, and the effect of steam or water filled into the gasoline engine is it can reduce fuel consumption by 6.44%, reduce NOx emissions by 40%, reduce HC 31.5% (Cesur *et al*, 2013). The using of water on diesel engine had ability in exhaust smoke reduction (Sahin *et al*, 2012).

From the advantages of ECP system and low temperature and moist air induct to the engine on performance and emissions, this research aims to study the influence of air that was reduced the temperature by ECP system on the intake air properties, performance and emission of the engine exhaust gas.

Materials and method

1) Test apparatus

The test apparatus from TecQuipment model TD201 use the single cylinder 4 strokes gasoline engine (Fig. 3) that had Bore size 70 mm, Stroke/Crank radius (mm) 54/27, Engine capacity 208 cm^3, Compression ratio 8.5 and Power 5.2 kW. The schematic diagram of this experiment was shown in Fig. 2. The engine shaft of test apparatus was connected to the shaft of the water break dynamometer. The intake air was pumping by the engine cylinder and flow through the evaporator (or ECP) to the engine cylinder. In this system, the intake air is not the warm air around the engine like an actual engine operation because the cooling system (evaporator) is adding and the air inlet duct is far from the engine (Fig.3). For solving this problem, the air heater was installed in the test apparatus to create and keep the warm intake air for the engine similar an actual engine operation.

2) Evaporative Cooling Pad (ECP)

The ECP model 7090 with a dimension of 30 x 27 cm^2 in W x H and 100 mm of thickness was modified to the intake air cooling system (Fig. 3). The water in the cooling system was flow through the pad and circulated between pad and water tank by electric pump.

3) Experiment

An intake air temperature was prepared in case of 1) warm intake air similar to the air around the engine at 50^oC - 55^oC and room humidity by use the air heater (not use the water in this case) 2) low temperature intake air by the use of evaporative cooling pad system (ECP) with the room temperature water and 3) very low temperature intake air by using the ECP system with cool water temperature of 0.5^oC. In the testing, the butterfly valve of the engine is wide open and breaks the engine with a constant load for investigating torque (N.m), fuel consumption (ml), air induction rate (kg/s) and emission in term of exhaust temperature (^oC) and HC (ppm) at the engine speed of 1,500, 2,000, 2,500, 3,000, 3,500 and 4,000 RPM respectively.

For the measurement, engine torque was measured by S-Type load cell. Air temperature and humidity were measured via a dry and wet bulb temperature of air with thermocouple type K. The engine exhaust emissions were analyzed by an automotive emissions analyzer (HORIBA Model MEXA-584L).

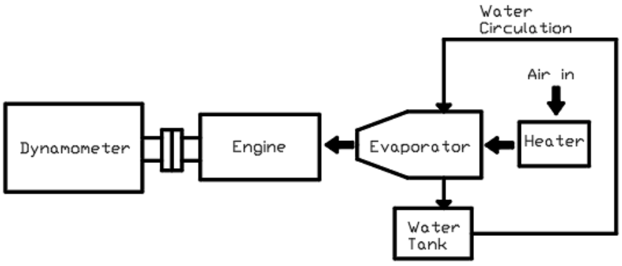

Figure 2: Schematic diagram of experiment system.

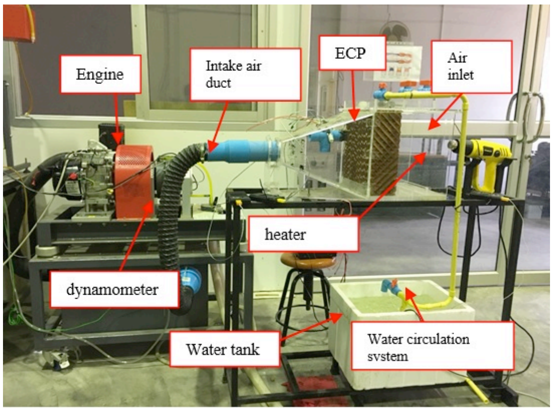

Figure 3: Equipment in the experimental system.

The engine performance was evaluated by (1) and (2) (Heywood, 1998)

$$W_b = 2\pi NT \quad (1)$$

Where W_b is engine break power (kW)

N is engine speed (rev/s)

T is engine torque (N.m)

$$b_{sfc} = \frac{\dot{m}_f}{W_b} \quad (2)$$

Where b_{sfc} is break specific fuel consumption (g/kW.hr)

$\dot{m}_f$ is rate of fuel consumption (kg/s)

Result and discussion

Table 1. Properties of intake air

Intake air	Temp. (°C)		Density (kg/m^3)	Absolute humidity (kg_{water}/kg_{air})	RH (%)
	Dry bulb	Wet bulb			
Warm temp.	52.8	34.3	1.0390	0.02705	29.8
Low temp.	31.1	26.6	1.1254	0.02098	75.2
Very Low temp.	21.9	16.8	1.1788	0.00985	60.1

The experiment results showed that the reducing of air temperature before taking into the engine with the ECP system effects on the air properties. From table 1. the inlet supplied air temperature to the test apparatus is equals in every experiment and constantly controlled the air temperature at 52.8°C (warm air) by the heater. On the first row of table 1. the warm air is not cooled by the ECP and directly intake to the engine with the high temperature, so the density of air is lowest. After the warm air is cooled by ECP (the 1st and 3rd rows of table 1.), the using of water at room temperature (around 23.7°C) in ECP system can reduces the temperature from 52.8°C to 31.1°C and can increases the air density to 1.1254 kg/m^3. This temperature reducing trend is similar to the case of very low temperature intake air when using the cool water at 0.5°C in ECP system. In term of moisture, the relative humidity is increasing when the intake air was cooled by ECP. In fact, the mass of water in air is not increase, on the other hand it is decrease because the dew temperature of the inlet air (warm air) is higher than the ECP temperature. As a result, a water in warm air is condensed at ECP and be the cool and dry intake air in finally.

The air density and temperature were used to calculated by Gas law (Cengel, 2004) to determine the intake air pressure and the relation between the pressure and engine speed was shown in Fig. 4.

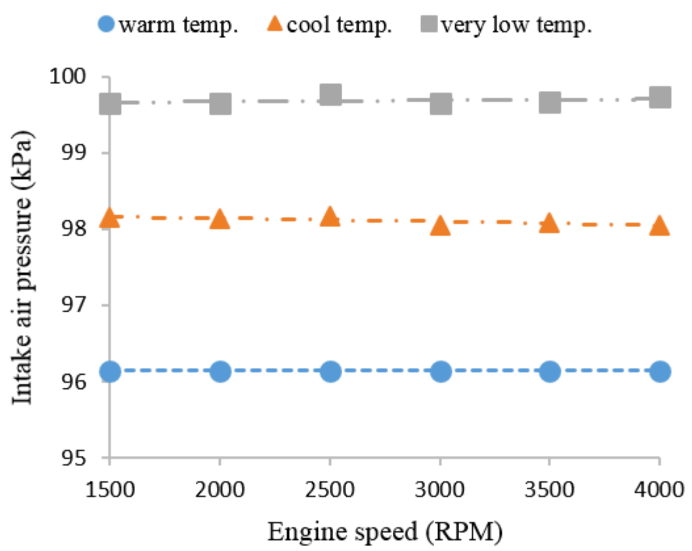

Figure 4: Relation between intake air pressure and engine speed.

From Fig. 4, the intake air pressure is almost unchanged when the engine speed increase. The effect of intake air temperature reducing is increased the intake air pressure because of the increasing of air density. At the very low temperature of intake air, the pressure is highest and increases closely to100 kPa.

For the measured torque that was produced by the engine, the result found the reducing of intake air temperature can increase torque in every engine speed. The magnitude of torque is increasing when the intake air temperature is more decrease and the maximum torque occur at 2,500 RPM engine speed. Because the higher air mass (by the increasing of air density) and pressure was induced to the engine, the maximum pressure in cylinder after power stroke is rising and create the higher torque in finally. The torque increases 3.21% at 2,000 RPM of engine speed (use water 23.7^{o}C in ECP) and 7.76% at 3,500 RPM (use water 0.5^{o}C in ECP) when compare to the warm intake air. This effect was shown in Fig. 5.

In term of the engine power from Fig. 6, when the engine speed increased, the power of the engine also increased too. Similar to the trends of increased torque when intake air temperature is reduced, the engine power is continuously increasing because it is the multiplied result of torque and engine speed, although the last engine speed the value of torque is decreased but the influence of speed in (1) is more effect than the value of torque.

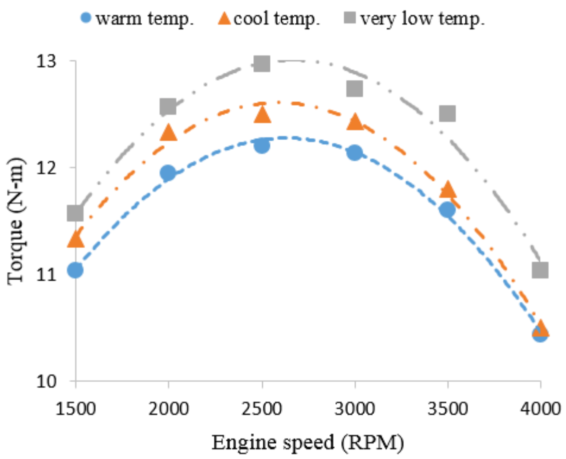

Figure 5: Relation between torque and engine speed.

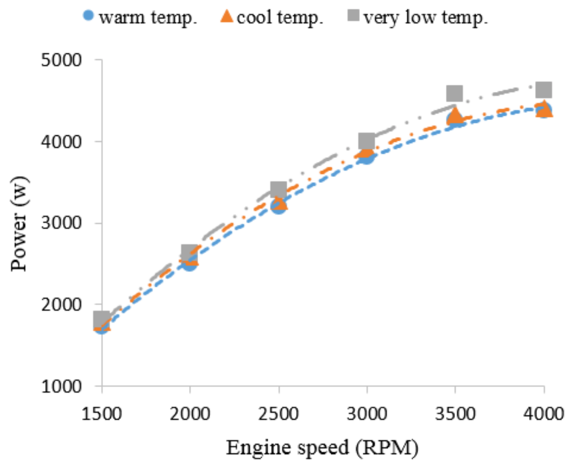

Figure 6: Relation between power and engine speed.

The fuel/air ratio of the cool intake air is reduced (Fig. 7) by the influence of air temperature reducing because the rate of fuel consumption is almost constant in any intake air temperature, but the air consumption has a rising trend when its temperature is decrease.

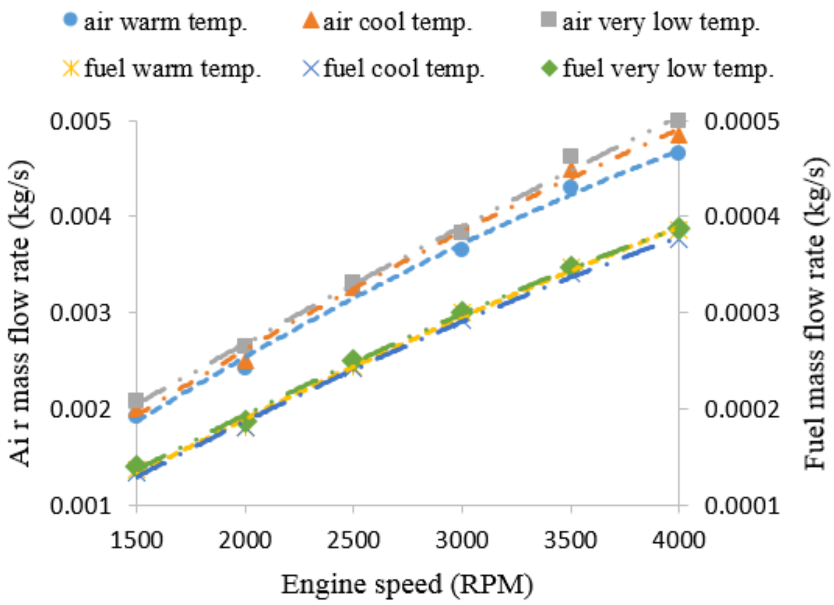

Figure 7: Relation between air (left axis) - fuel (right axis) consumption and engine speed.

The relation between the b_{sfc} and speed of the engine is presented in Fig. 8, the b_{sfc} was decreased when engine speed increase from 1,500 to 2,500 RPM and after that tend to increase when the engine speed is increased of every intake air temperature. Considering on intake air temperature found that when the intake air temperature is reduced, the b_{sfc} of the engine was decreased because the power of engine was clearly increased (fig.6) while the fuel consumption was slightly increased (fig.7). The b_{sfc} of the engine was decreased 5.54% at 1,500 RPM of engine speed (use water 23.7^{o}C in ECP) and 7.04% at 3,500 RPM (use water 0.5^{o}C in ECP) when compare to the warm temperature intake air.

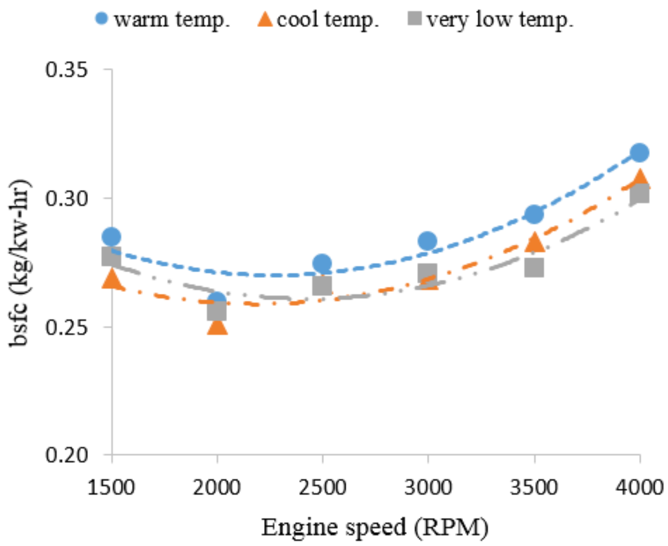

Figure 8: Relation between break specific fuel consumption (b_{sfc}) and engine speed.

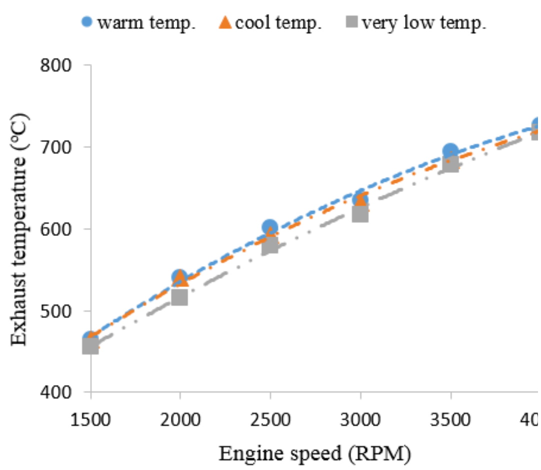

Figure 9: Relation between exhaust gas temperature and engine speed.

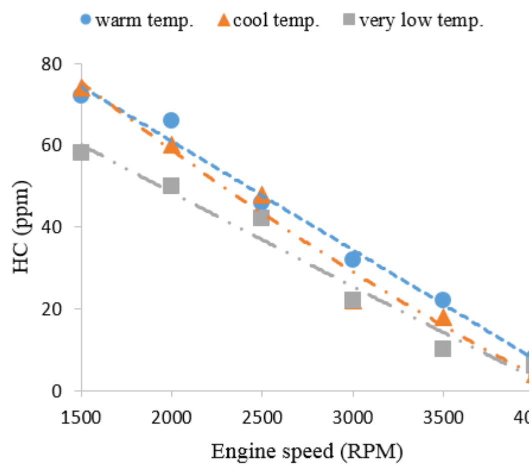

Figure 10: Relation between HC emission and engine speed.

Fig. 9 is present the relation between exhaust gas temperature and engine speed. When the engine speed increases the exhaust gas temperature from the engine also increased too. The very low temperature intake air was produced the lowest exhaust gas temperature when compare with the warm and low temperature intake air because the intake air temperature to the engine is lowest and when this air was finished the combustion, the exhaust gas in cylinder is not also heating over. Considering on HC emission found that the HC-emission of the engine was decreased when the engine speed increased (Fig. 10) and the reducing of intake air temperature affect to the decrease of HC emission because the rising of intake air mass in the engine cylinder help the combustion completely. The HC emission decrease 31.25% at 3,000 RPM of engine speed (use water 23.7^{o}C in ECP) and 54.55% at 3,500 RPM (use water 0.5^{o}C in ECP) when compare to the warm intake air.

Conclusions

The reducing of intake air temperature by ECP system affect to the increasing of density, relative humidity and pressure of the intake air to the engine. The lower temperature of intake air affect to the engine power increases 3.21% at 2,000 RPM (use water 23.7^{o}C in ECP) and 7.76% at 3,500 RPM (use water 0.5^{o}C in ECP), the break specific fuel consumption of the engine decreases 5.54% at 1,500 RPM (use water 23.7^{o}C in ECP) and 7.04% at 3,500 RPM (use water 0.5^{o}C in ECP), the exhaust gas temperature is decreased and the HC emissions decreased 31.25% at 3,000 RPM (use water 23.7^{o}C in ECP) and 54.55% at 3,500 RPM (use water 0.5^{o}C in ECP) when compare with the warm intake air.

Acknowledgement

The authors wish to acknowledge the Biosystem Engineering and Technology Research Unit, Suranaree University of Technology for the research support.

References

Cengel, Y. A. (2004). *Thermodynamics an Engineer Approach*. New York city: McGraw-Hill Science.

Cesur, I., Parlak, A., Ayhan, V., Boru, B., & Gonca, G. (2013). The effects of electronic controlled steam injection on spark ignition engine. *Applied Thermal Engineering*, *55,* 61-68.

Heywood, J. B. (1998). *Internal combustion engine fundamentals*. Singapore: McGraw-Hill.

Martínez, P., Ruiz, J., Cutilas, C. G., Martínez, P. J., Kaiser, A. S., & Lucas, M. (2016). Experimental study on energy performance of a split air-conditioner by using variable thickness evaporative cooling pads coupled to the condenser. *Applied Thermal Engineering*, *105,* 1041-1050.

Papakae, S., Nuekawai, W., Boonngern, K., Siriwatcharachaikun, R., Treeamnuk, K., & Treeamnuk, T. (2017). Numerical analysis of Thermodynamics Performance of Gasoline Engine. Presented at the 2nd National Conference on Informatics, Agriculture, Management, Business Administration, Engineering, Sciences and Technology (IAMBEST 2017), Chumphon, Thailand. 31 May-1 June 2017.

Sahin, Z., Tuti, M., & Durgun, O. (2012). Experimental Investigation of the effects of water adding to the intake air on the engine performance and exhaust emission in a DI automotive diesel engine. *Fuel*, *115,* 884-895.

Sajovaara, T., Larmi, M., & Vuorinen, V. (2015). Effect of charge air temperature on E85 dual-fuel diesel combustion. *Fuel, 153,* 6-12.

Contact email: tawarat@sut.ac.th, krawee@sut.ac.th, sakkarinpapakae@hotmail.com