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The Effect of Intake Air Temperature on Spark Ignition Engine Performance

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Abstract: This study of experimental study shows the effect of ambient air temperature for four seasons in Iraq on spark ignition engine performance by using gasoline fuel. The engine was used in this resaerch has a cooled single cylinder spark ignition engine. The intake air temperature range was (10-60°C) were subjected according to the temperature changes in different seasons of the year in Iraq. The goal of that was to check the engine performance. The operation speed of the SI engine was changed from (1400-3000 rpm). The air box is provided with an electrical heater to raise the temperature of the entering air. The experimental outcomes contain a reduction in fuel consumption up to (18.9%), brake specific fuel consumption up to 15.4%, however, the thermal brake efficiency increased by about (4.4%). The exhaust gas emissions revealed a decrease almost (11%) of CO and (7.31%) of HC, however, increasing CO_2 emission by (15.05%) and NOX emissions by 19.33%.

Key words: Combustion, intake air temperature, spark ignition, performance, intake, operation

INTRODUCTION

The high cost of the gasoline fuel and the emissions produced as a result of gasoline fuel combustion which changes the global climate make engine researcher, manufacturer and designer looking for the cause the effect on engine performance. The engine operating conditions like air properties, humidity and temperature affected directly on engine performance. The increasing in inlet air temperature not more than 60°C causes enhancing to the fuel evaporation process also raise the temperature of the end charge at the last compression stroke this will cause raise the combustion efficiency. The air above heating process causes a reduction in air density there for the oxygen concentration in the air will lessen, so that, the combustion efficiency (Niimi, 2006).

Sahu *et al.* (2016) investigated experimentally the effect of incoming air preheating on engine thermal efficiency, emissions and fuel consumption. The enginewas used in the experimental work was four strokes, single cylinder, air-cooledspark ignition engine. The intake air temperature was raised by using air preheated box. The practical results show the air preheating process rise the engine thermal efficiency and nitrogen oxides emissions but lower the fuel consumption and carbon monoxide emissions due to increase in combustion process temperature. Rakesh and Simhadri (2016) studied the effect of intake air temperature on single cylinder air-cooled SI engine fuel with (gasoline-ethanol) dual fuel. The inlet air is preheated by using waste exhaust heat. The experimental results show better improvement in brake specific fuel consumption and thermal brake efficiency with a percentage of 5.43, 5.4%. Aziz and Fuad (2015) studied the effect of ambient air temperature on single cylinder four-stroke air-cooled overhead valve engine. The engine factor measured at a different inlet air temperature were specific fuel consumption, engine thermal efficiency and emissions which are produced by the combustion process. The experimental results manifested the increase in inlet air temperature reduce the fuel consumption and engine emissions but increase the power output. The inlet air temperature in which the engine was tested were 30, 35, 40 and 45°C.

Rameshbabu and Arunkumar (2015) studied the effect of air preheating on single cylinder four-stroke engine cooled by air. The preheating process of airis accomplished via. placing a heat exchanger inside the engine muffler to exchange the heat between the incoming air and exhaust gases without mixing. The experimental results illustrated the incoming air preheating process via. recover the heat in the exhaust system rise the engine brake thermal efficiency, indicates thermal efficiency and engine mechanical efficiency. On the other hand, Davis *et al.* studied the influence of increasing the inlet air temperature on spark ignition engine performance. The experimental work was accomplished by using Honda CD-100 four strokes, single cylinder engine, air cooled and

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overhead came. The practical results show the increase in inlet air temperature rise the engine show, brake and mechanical efficiencies but reduce the engine fuel consumptions. Rahman *et al*. (2014) studied the influence of increasing the temperature of incoming air and inlet bioethanol fuel. The engine used in this experimental work was effected the engine performance of improved brake power, brake specific fuel consumption and reduced emissions of SI engine.

Perumal and Manoj (2015) studied the effect of rising the incoming air temperature on engine performance. The experimental work was accomplishedvia using single cylinder gasoline engine provided with air preheated which was placed before engine carburettor to enhance the fuel evaporation process. The last experimental results show the air preheating process reduce the percent of unburned hydrocarbon and carbon monoxide emissions. Malaisamy and Balashanmugam (2014) studied the effect of inlet air preheating by using exhaust waste heat on a single cylinder, air-cooled SI engine performance. The engine emissions were measuredat a different engine load which was varied from 25-100% into 25% increment. CO ratio of two-stroke single-cylinder engine is 5.20, 5.51, 5.45, 7.19 at altered load condition (25, 50, 75, 100%). With the use of the heating chamber, the percentage of CO is 4.84, 5.02, 5.14, 6.80. A similar percentage of HC is reducing the use of heating chamber.

Yoon and Lee (2012) studied the impact of intake air temperature on spark ignition engine performance fueled with bioethanol. The inlet air temperature range in which the engine was examined was (10, 30, 50°C). The investigated results show that as intake ambient air temperatures are decreased, the in take flow rates are increased by the increased density of the in take air. The concentration of NOx emissions tends to increase proportionally with the increase in ambient air temperature and engine speed for all test conditions, the greatest increase in NOx emissions is 25%. However, the HC emissionis reduced up to 25%. The brakepower and brake specific fuel consumption were reduced into a percentage of (18, 8%).

Zheng *et al*. (2009) studied the impact of increasing the intake temperature on the pressure in the cylinder. The experiment was carried out in a CT2 100 Q engine which is a double cylinder, four strokes, compulsory water cooling, naturally aspirated and direct injection. The primary analysis revealed that with the increase in intake temperature, the carbon monoxide and hydrocarbon emissions decrease. The emission of oxides of nitrogen increases with the increase in intake temperature. However, Weilenmann *et al*. (2005) studied the impact of cold ambient temperature on engine emissions. The practical result manifests increasing the emissions of unburned hydrocarbon and carbon monoxide but the nitrogen oxide will have decreased. This research aims to study the influence of intake air temperature during the suction stroke on engine performance and emissions. The difference between this research and the previous works is the range of inlet air temperature. The difference in results between this research and previous papers can be attributed to the following points:

- The test rig component design which includes engine capacity, dynamometer type, the range of the load, the range of inlet air temperature variation
- The fuel properties such as density, viscosity, flash point temperature, surface tension, heating value, octane number and chemical composition of the fuel
- A range of the inlet air temperature and lab room temperature whichare affected directly by heat transfer rate out of the engine by the cooling system

MATERIALS AND METHODS

Engine performance mathematical model: The engine performance can be following a simple model of equations based on heat engine thermo dynamics (Imran and Kurji, 2018):

Fuel mass flow rate:

$$\dot{m}_f = \frac{V_F}{Time} \times \rho_F \text{ kg/sec} \quad (1)$$

Brake power:

$$bp = \frac{2\pi * N * T_b}{60*1000} \text{kW} \quad (2)$$

Brake specific fuel consumption:

$$bsfc = \frac{\dot{m}_f}{bp} \times 36000 \frac{kg}{kW.h} \quad (3)$$

Air consumption (SI engine):

$$\dot{m}_{a,act.} = \dot{V}_a \times A_c \frac{kg}{sec} \quad (4)$$

$$A_c = \frac{\pi}{4} D^2$$

Brake thermal efficiency:

$$\eta_{bth.} = \frac{bp}{\dot{m}_f * LCV} \quad (5)$$

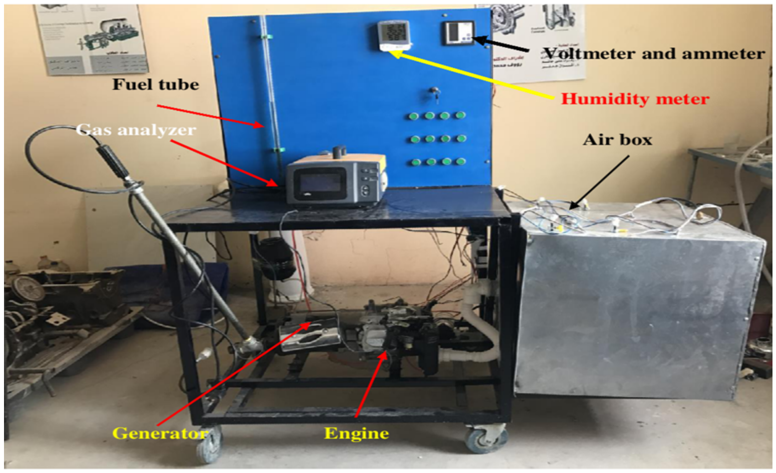

Fig. 1: Combustion system test rig

Where:

V_F = The Volume of Fuel consumption
ρ_F = The density of fuel (kg/m^3)
N = Rrotational speed (rpm)
Tb = Torque of engine (N.m)
AC = Intake manifold area (m^2)
D = Intake manifold diameter (m)
∇P = Pressure differences by the manometer
LCV = Low heating value (J/kg)

Experimental work: The experimental work of this resaerch was achieved at the laboratories of the Department of Mechanical Engineering of Kerbala University. The test rig was totally designed and manufactured locally by engineering laboratory supplies according to the plan needed to achieve the goal of research.

Experimental setup: The internal combustion engine which is shown in Fig. 1 contains single cylinder four strokes, air cooled spark, ignition engine with a capacity of 175 cm^3 attached with an electric dynamometer. The dynamometer connected to the variable electric load. The electrical load is divide into ten steps with 300 W increment. The current and voltage which are provided to the load can be measured by using a digital voltmeter and ammeter to measure electric power which is represented as brake power. The operation condition of air temperature and humidity can be controlled by using a mixing box provided by an electric heater and water source to increase the temperature and humidity of the combustion air. The heat which is gained by air during passes through the mixing box is controlled by using a thermostat. The humidity and temperature of the incoming air were measured by using humidity meter and ther mometer the test rig is provided with fuel measure system which comprises from stop watch and graduated glass tube. The engine speed and engine emissions can be measured by using gas analyser type (mod 488-Italy). The gas analyser measures the concentrations of carbon monoxide, carbon dioxide, unburned hydrocarbon and nitrogen oxide in products of combustion. All the mentioned components are fitted on the iron structure.

The system of measuring and change the properties of consumed air: The air supplied to the engine was measured by installing the hot wire in the inlet air pipe to measure the velocity of the air through the pipe. The air mass flow rate can be calculated according to the equation number four. Also, the thermometer is installed in the inlet air pipe to measure the humidity and temperature of the air as shown in Fig. 2. The air mixing box which is shown in Fig. 1 has a dimension of (60×60×60) is used to control on engine operation condition humidity and temperature of the inlet air. The electric heater which is shown in Fig. 3, installed in the mixing box to heating the air. The air temperature controlled by an installed electrical thermostat in the mixing box which is shown in Fig. 4. The inlet air humidity controlled by injected the water into the mixing box which includes hot air heated by an electric heater to enhance the injected water droplets evaporation and to increase the humidity of the combustion air. The water injection system comprises from the water pump is used to deliver the water to the water nozzle at pressure 9 bar.

The water nozzle is used to inject the water into small diameter droplets to increase the outer surface area exposes to hot air to evaporate the water droplets at a short period. The humidity of the combustion air controlled through the water pump inlet valve.

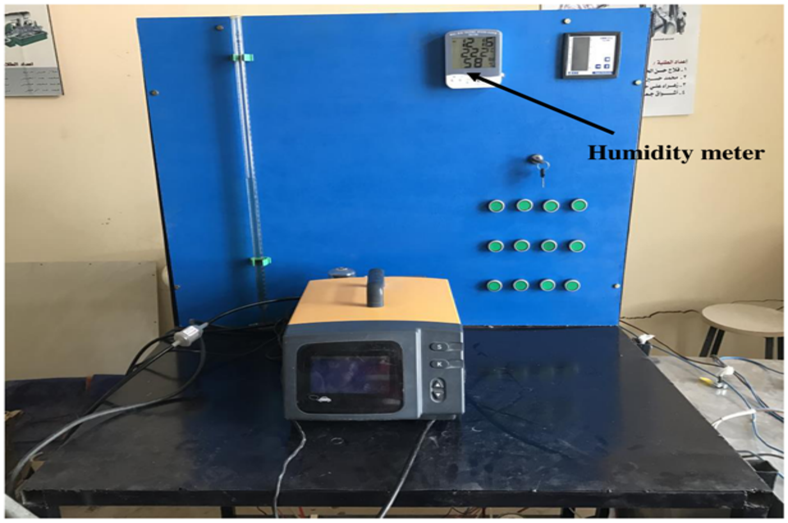

Fig. 2: The position of the magnetic field on the outer surface of the fuel pipe line

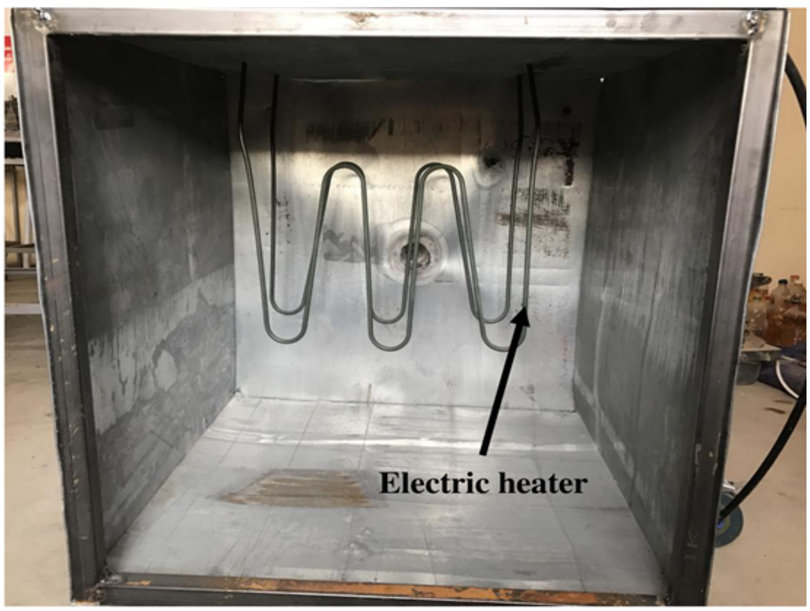

Fig. 3: The electric heater installation inside a mixing box

Experimental procedure: The following steps were done to implement the experimental work: prepare the engine and the measurement devices to read the data for the natural case. Measuring engine speed, brake torque and the time of fuel consumed for the volume of (100 mL) (Table 1) at a different range of air properties (humidity and temperature).

Record all data when changing the temperature of the air which is regulated by using a thermostat and the water valve which controls the amount of water which injected at later in the mixing box.

RESULTS AND DISCUSSION

The results obtained from the experimental work are presented here to demonstrate the effect of increasing inlet air temperature on engine performance. The main operating variables expected to be affected by increasing the inlet air temperature are break power, specific fuel consumption, engine emission and magnetic field intensity. The major results can be sum up through the following concluded remarks (Fig. 4 and Table 1). The increasing in inlet air temperature reduce the fuel

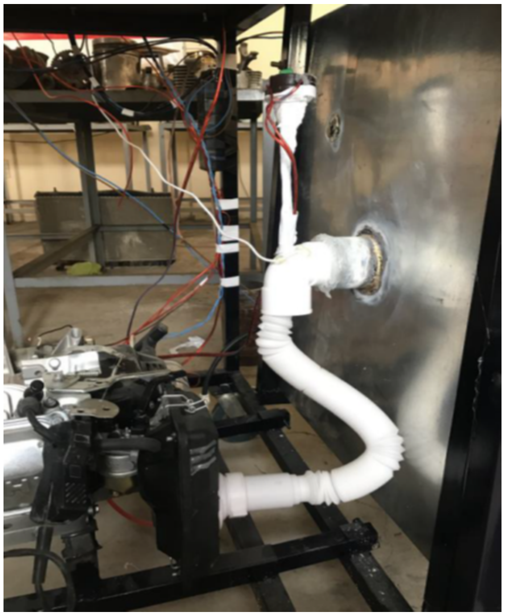

Fig. 4: The thermostat position

Table 1: Main technical specifications of spark ignition engine

Spark ignition engine	Specifications
Engine type	Single cylinder, four stroke
Engine model	95310
Ignition timing	25° (BTDC)
Displacement	118 (cm^3)
Valve per cylinder	Two
Stroke	42 (mm)
bore	60 (mm)
Compression ratio	7.5
Engine cooling type	forced air cooled
Lubrication	Forced lubrication
Engine oil capacity	0.6 L

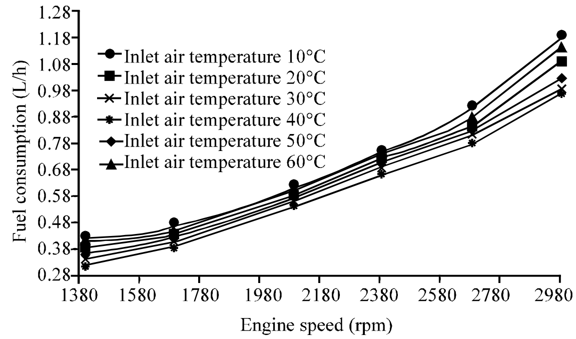

Fig. 5: Fuel consumption (L/h) as a function of engine speed for SI engine with increased the inlet air temperature

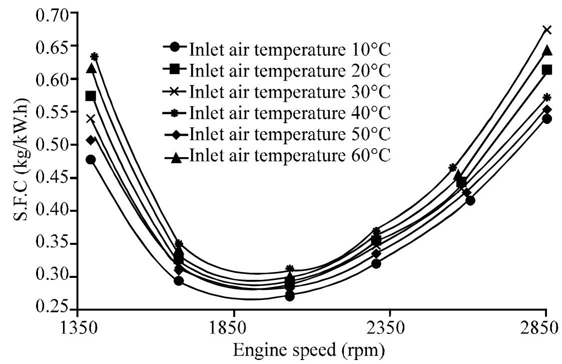

Fig. 6: Brake specific fuel consumption (bsfc) as a function of engine speed for SI engine with increasing the inlet air temperature

consumption. The inlet air temperature is increased from 10-60°C into 10°C, increment, the engine fuel consumption have decreased as shown in Fig. 5. The maximum reduction in fuel consumption occurs when rising the inlet air temperature to 60°C. The experiment revealed that the fuel consumption is reduced up to (9.2, 17.9, 18.9%) for the (SI engine) when increasing the temperature of inlet air into values of 20, 40, 60°C, respectively. This behaviour of fuel consumption reduction attributed to that the high temperature of inlet air enhances the fuel evaporation to give a homogenous mixture. Also, the inlet air preheating increases the average temperature at which heat is added, so that, the fuel consumption will decrease.

It can be seen that the brake specific fuel consumption (bsfc) decreased as shown in Fig. 6. When preheating the incoming engine air, the maximum reduction was measured to be approximately by (2.8, 9.14, 15.4%) at inlet air temperature (20, 40, 60°C), respectively. This behavior of reduction in specific fuel consumption attributed to that the air-preheating rise the rate of fuel evaporation process in this situation the fuel vapor atoms will distribute in equal portions approximately within preheated incoming air there for a better mixiproduce a homogenous mixture. In additional the air pre-heating process rise the average temperature at which heat is added in this situation the mean effective pressure in the engine cylinder will rise and increase the engine work.

The brake thermal efficiency results are shown in Fig. 7 for different engine speeds. The increasing of the inlet air temperature rises the thermal brake efficiency into maximum value by about (0.4 , 2.4, 4.4%) at the inlet air temperature (20, 40, 60°C), respectively. This behavior of increasing in engine thermal efficiency attributed to that the increasing the inlet air temperature enhances the fuel evaporation process, so that, the homogenous mixture will produce due to the rise of the inlet air temperature. Also, the high temperature of incoming air and fuel mixture rise

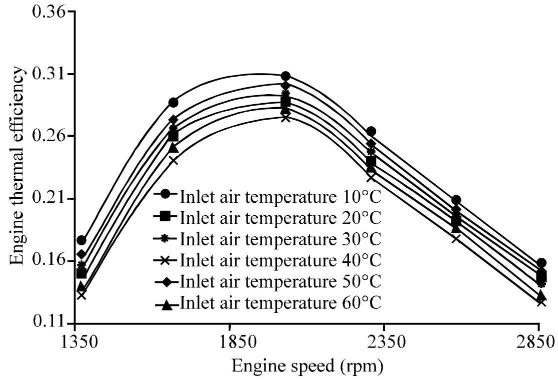

Fig. 7: Brake thermal efficiency as a function of the engine

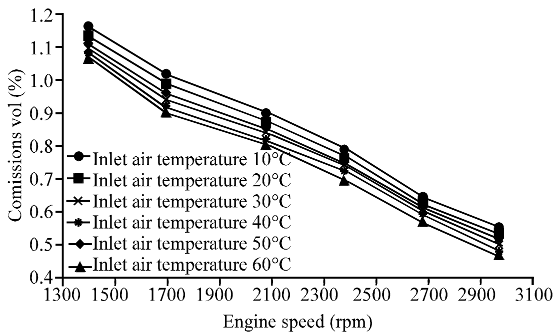

Fig. 8: The percent of (CO) as a function of engine speed

the average temperature at which heat is added, so that, the combustion efficiency will rise to maximum value.

The percentage of the exhaust gases were measured during the operation of the engines for different engine speeds and the results between different values of inlet air temperature are compared. Figure 8 shows the variation emissions of CO with engine speed measured experimentally from the combustion of gasoline fuel compared with the emissions of CO from the same fuel when inlet air temperature is increased form 10-60°C with 10°C increments. It was found that for this range engine speeds, drop in CO emissions when increasing the temperature of the inlet air. The experiment revealed that CO concentration is reduced up to (3, 7, 11%), respectively for the (SI engine) when increasing the temperature of inlet air into vales of (20, 40, 60°C), respectively. That may be due to the air preheating process evaporate the fuel before entering within the combustion chamber in this situation the residence time of CO within the combustion chamber is increased, so that, the time of CO atoms meeting or reacted with oxygen to form CO_2 and heat is increased. The increasing in reaction time of CO and oxygen causes a reduction in the level of CO emissions.

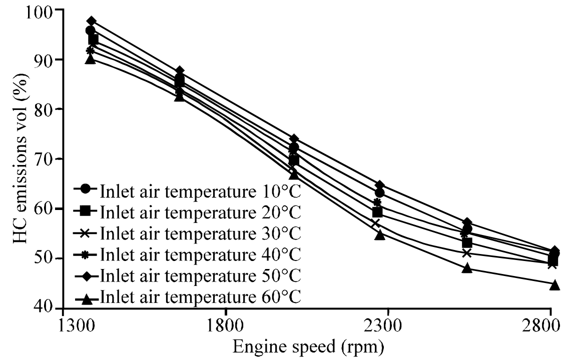

Fig. 9: The (HC) concentration as a function of engine speed

Figure 9 shows the variation emissions of HC with engine speeds measured experimentally from the combustion of gasoline fuel compared with the emissions of HC from the same fuel when inlet air preheated. From the graph, HC concentrations decrease when the engine inlet air temperature is increased. The experiment revealed that HC concentration is reduced up to (1.56, 6.25, 7.81%) for the (SI engine) at inlet air temperature (20, 40, 60°C). That may be due to the air preheating process evaporate the fuel droplets during induction stroke. The latent heat of fuel vaporisation gained from air preheating process. The fuel vapour molecule weight lower than fuel droplet weight in this situation the fuel vapour molecule will be distributed in flowing stream of air within intake manifold in equal portion approximately in the radial direction to produce a homogenous mixture. The good distribution of oxygen atoms within air stream in homogenous mixture gives high efficient combustion which leads to burning all fuel molecules within the combustion chamber, so that, the level of HC emissions will be reduced.

Figure 10 displays the variation emissions of CO_2 with engine speeds measured experimentally from the combustion gasoline fuel compared with the emissions of CO_2 when increased the temperature of combustion air. The experiment revealed that CO_2 concentration is reduced up to (1.3, 9.58, 15.05%), respectively for the (SI engine) with increasing the temperature of incoming air (20, 40, 60°C). The increasing in CO_2 emissions due to produce homogenous mixture via. using air preheating process. The homogenous mixture has sufficient oxygen to complete the combustion process and complete hole CO molecule to CO_2 and heat.

The variation emissions of NOX with engine speeds measured experimentally from the combustion gasoline fuel compared with the emissions of NOX when

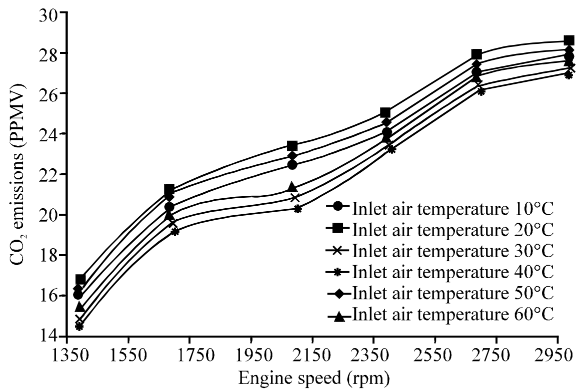

Fig. 10: The (CO_2) concentration (ppm) as a function of engine speed

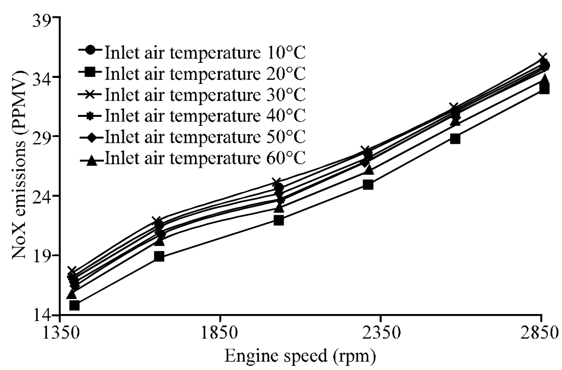

Fig. 11: The percent of (NOX) as a function of engine speed

increasing the inlet air temperature as shown in Fig 11. NOX concentrations increased by 6, 13.33, 19.33% with increasing the inlet air temperature (20, 40, 60°C). That may be due to the air preheating process evaporate the fuel droplets during induction stroke and produced a homogenous mixture, so that, the combustion temperature will be increased with in combustion chamber in this situation all the fuel atoms will be burned during the combustion process there for the level of NOX emissions will be increased.

CONCLUSION

From the experimental results obtained in the present study for the spark ignition engine performance running on unleaded (gasoline) with inlet air pre-heating the following conclusions can be stated and as follows.

The experiment revealed that fuel consumption is reduced up to (9.2, 17.9, 18.9%) for the (SI engine) when increasing the temperature of inlet air into vales of (20, 40, 60°C), respectively. The inlet air preheating process reduced the specific fuel consumption the maximum reduction is (15.4%) when the inlet air temperature 60°C. The increasing in inlet air temperature causes an increase in thermal brake efficiency the maximum increasing is (4.4%) at inlet air temperature 60°C. The air preheating process reduced the emissions of CO and HC up to (11, 7.81%), respectively but increase the emissions of NOX and CO_2 up to (19.33, 15.05%) when the inlet air temperature 60°C .

REFERENCES

Aziz, A. and M. Fuad, 2015. The effect of ambient temperature to the performance of internal combustion engine. Master Thesis, Universiti Tun Hussein Onn Malaysia, Parit Raja, Malaysia.

Imran, M.S. and H.J. Kurji, 2018. The effect of using waste corn oil on compression ignition engine performance. Intl. J. Appl. Eng. Res., 13: 3966-3974.

Malaisamy, A. and P. Balashanmugam, 2014. Fabrication of efficiency increaser by using preheating method. Intl. J. Sci. Res., 3: 1-3.

Niimi, K., 2006. Internal combustion engine. Google Patents, 1: 1-12.

Perumal, K.R. and R. Manoj, 2015. Reduction of hydrocarbon by preheating air-fuel mixture by flue gas in S.I. engines. Intl. J. Mech. Eng. Rob., 3: 19-21.

Rahman, M.N., N. Atan, A. Mokhtar and A. Khalid, 2014. Influences of intake temperature and bio-petrol fuel temperature on SI engine: An overview. Proceedings of the 2014 International Conference on International Integrated Engineering Summit (IIES 2014), December 1-4, 2014, Universiti Tun Hussein Onn Malaysia, Parit Raja, Malaysia, pp: 1-5.

Rakesh, A. and K. Simhadri, 2016. Experimental investigation on performance characteristics of four stroke single cylinder petrol engine using a pre-heating set-up and fuel blends. J. Cylinder Petrol Engine, 14: 2198-2210.

Rameshbabu, A. and K. Arunkumar, 2015. Increase engine efficiency by using inlet air preheating method through exhaust gas temperature with convective mode of heat transfer. Intl. J. Sci. Eng. Res., 4: 32-34.

Sahu, R.K., S.S. Rat, P. Beheramali and G. Das, 2016. Performance analysis of an engine by fabricating an air Preheater for petrol and diesel engine. Intl. J. Eng. Stud. Tech. Approach, 2: 77-83.

Weilenmann, M., P. Soltic, C. Saxer, A.M. Forss and N. Heeb, 2005. Regulated and nonregulated diesel and gasoline cold start emissions at different temperatures. Atmos. Environ., 39: 2433-2441.

Yoon, S.H. and C.S. Lee, 2012. Effect of undiluted bioethanol on combustion and emissions reduction in a SI engine at various charge air conditions. Fuel, 97: 887-890.

Zheng, J.J., J.H. Wang, B. Wang and Z.H. Huang, 2009. Effect of the compression ratio on the performance and combustion of a natural-gas direct-injection engine. Proc. Inst. Mech. Eng. Part D. J. Automobile Eng., 223: 85-98.