STUDY PERFORMANCE AND EMMISSION OF DIESEL ENGINE FUELED WITH DIFFERENT DIESEL FUEL TEMPERATURES

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ABSTRACT

An experimental study was carried out by using a portable apparatus that was locally collected, used to control the temperature of diesel fuel. It was connected and tested with the line of fuel supply system for agricultural tractor (Anter-71) diesel engine which running under different speeds. An experiment was conducted during June, 2014 in practical route in the Department of Machines and Equipment, Collage of Agriculture, University of Baghdad. Different inlet fuel temperatures included 40,45and 50°C and speeds included 1000, 1500 and 2000rpm were studied in this research. The engine performance parameters which included, Fuel consumption FC, exhaust gas temperature EGT, Un-burnt Hydrocarbons UHC and Nitrogen Oxide NO_X, were measured under different speeds. Treatment data were analyzed by using SAS 2000 statistical program factorial design under Complete Randomized Design (CRD), with three replications and LSD; 5%were used. Results were showed that, fuel temperature at40°C indicated significant superiority up on fuel at temperatures 45, and 50°C in achieving lower fuel consumption, exhaust gas temperature EGT, Un-burnt Hydrocarbons UHC and Nitrogen Oxide NO_X, for all speeds, while fuel temperature at 50°C achieving higher fuel consumption. Increasing engine speeds from 1000, 1500 and to 2000 rpm caused an increasing in FC, exhaust gas temperature EGT, Un-burnt Hydrocarbons UHC and Nitrogen Oxide NO_X. Speed of 1000rpm achieved lower fuel consumption, and lower EGT, UHC and NO_X, while engine speed at 2000rpm recorded significant superiority up on 1000and 1500rpm in achieving higher fuel consumption FC,EGT,UHC and NO_X .

Keywords: Un-burnt Hydrocarbons HC, Exhaust gas temperature, Emission Nitrogen Oxide.

***Part of M.Sc. thesis of the second author.**

دراسة اداء وانبعاثات محرك الديزل يعمل بوقود ديزل في درجات حرارة مختلفة

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المستخلص

أنجزت دراسة تجربة باستخدام جهاز تم تجميعه محليا للسيطرة على درجة حرارة وقود الديزل. تم ربط الجهازواختباره على منظومة تجهيز الوقود لمحرك الجرار نوع عنتر -71. استخدمت في التجربة ثلاث مستويات من درجات الحرارة وهي 40 ، 45، و 50 م°، ثلاث مستويات من السرع هي 1000 و1500 و2000 دورةا دقيقة على التتابع لغرض تقييم بعض مؤشرات الاداء لمحرك الجرار التي تشمل، أستهلاك الوقود FC ودرجة حرارةغازات العادم EGT والغازات غير المحترقة HC واكاسيد النتروجين NOx نفذت التجربة خلال شهر حزيران،2014 في قسم المكائن والالات الزراعية في كلية الزراعة/جامعة بغداد، استخدم البرنامج الاحصائي SAS , 2000 في استخلاص نتائج الدراسة وفق نظام الالواح المنشقة، التصميم العشوائي الكامل (Complete Randomized Design (CRD وبثلاثة مكررات، استعمل اقل فرق معنوي بمستوى 5% لمقارنة متوسطات المعاملات. وكانت النتائج كمايلي: أدت زيادة درجات الحرارة للوقود من 40،الى45ثم الى50م° الى زيادة في معدل أستهلاك الوقود، اذ تفوقت درجة حرارةالوقود 40م° على درجات حرارة الوقود الاخرى (45 و50 م°) في تحقيق اقل معدل استهلاك للوقود واقل درجة حرارة لغازات العادم، وايضا اقل معدل للغازات غير المحترقة واكاسيد النتروجين بينما سجلت درجة حرارةالوقود 50 م° اعلى معدل استهلاك للوقود واعلى درجة حرارة لغازات العادم واعلى معدل للغازات غير المحترقة واكاسيد النتروجين. ادت زيادة السرعة للمحرك من 1000الى 1500ثم الى 2000 دورة/ دقيقة الى زيادة في معدل استهلاك الوقود، ودرجة حرارة غازات العادم والغازات غير المحترقة واكاسيد النتروجين حيث تفوقت السرعة 1000 دورة/ دقيقة في تحقيقها اقل معدل استهلاك للوقود بينما تفوقت سرعة المحرك 2000 دورة/ دقيقة على السرع الاخرى في تحقيق اعلى معدل استهلاك للوقود واعلى درجة حرارة لغازات العادم واعلى معدل للغازات غير المحترقة واكاسيد النتروجين.

كلمات مفتاحية: الهيدروكربونات غير المحترقة، درجة حرارة غازات العادم، انبعاثات اكاسيد النيتروجين.

***البحث مستل من رسالة ماجستير للباحث الثاني.**

INTRODUCTION

Diesel engine is a most important power source and an essential contributor in sectors of construction, transport, agriculture, and electrical generator, marine. etc. These power plays a vital role in the economic growth of nations and environment, so engine provides power which abstracted from fuel combustion or oxidation. The availability of the fuel, its price and the combustion characteristics considered a major parameter for the user. Therefore the fuel combustion produces useful power and a large amount of exhaust emissions (8). Exhaust gases which considerably toxic gases that lead to environmental contaminations which harmful to human beings and plants. Recently research scientists have been focused their interests to improve fuel characteristics and reduce its emissions. Due to the shortage of fuel reserves and increasing environmental problems. They are testing another ways like, controlling fuel temperature which has an important effect on the performance of internal combustion engines, while others used alternative biofuel which was represented most important alternative for diesel fuel (13, 14). Electronic Control Unit (ECU) considerably most efficiency fuel metering device in internal combustion engines to contributes in order to save petroleum fuel (12). Fuel temperature plays a vital role on fuel consumption and exhaust gas emission of diesel engine, since its effect on the properties which include the density and viscosity, when temperature increase density and viscosity are decreased. Consequently led to increase engine fuel consumption and emissions (4, 5, 16). Researchers reported that higher values of fuel consumption were observed at preheated condition of fuel (9,17). Engine speed represents other common factor by its effecting on engine fuel consumption as (12) observed that speed has affected on engine performance, fuel consumption increase at higher speeds, due to the friction loss between engine moving parts increases, which requires more fuel consumption (16). This study was executed according to split plots under Complete Randomized Design (CRD) with three Replications. Two factors were studied according to this design namely: fuel temperatures included 40, 45, and50°C. And engine speeds included 1000, 1500 and 2000 rpm. Least Significant Differences (LSD) were used to compare means of treatments at %5 levels. The statistical analysis was carrying out by using program. SAS, (2000). This study has been written with perspective to investigate the effect of diesel fuel temperature on engine fuel consumption and emission. For suitable using an apparatus must be connected with fuel supply line to control the temperature of diesel fuel that delivered to the engine.

The objectives:

The objectives of this research can be summarized as follows:* Assembly an apparatus to control fuel temperature that delivered to the engine of Anter 71 tractor. * Measuring some engine performance indicators. Due to the effect of fuel temperatures, and speed

Materials and methods Tractor

The study is conducted on an agricultural tractor, specifications of tractor engine showedin table (2). The speed of the engine was measured by using digital tachometer type (DT-2234C).

Diesel fuel

The conventional pure diesel fuel supplied via AL- Dura Refinery, was used in this research. The fuel was analyzed to test its physical properties under selected temperatures in laboratories of Oil Training Institute–Baghdad; the results of the fuel analysis were shown in table.(1).

Exhaust gas temperature thermometer

Exhaust gas temperature was measured by an analog gauge which was contacted with exhaust gas manifold, close to engine cylinder block. The temperature is directly displaced from 0 to 1000°C.

Control temperature apparatus.

This device is consist of a lot of parts to carry out its task which was controlling on inlet fuel temperature, all these parts were assembled as a compact unite figure (1) .

Scaled fuel tank, Scaled fuel tank was connected to the fuel supply system, used for measuring fuel delivered to test engine. The amount of consumed fuel was directly read out from scaled plastic transparent tank with capacity of two liters. Delivery fuel flows into volumes of 20 ml for recording specified time (t)when engine consumes 20 ml of diesel fuel at variant time .

Radiator, Air conditioning radiator (made of aluminum alloy 422x323mm, was used as a cooling unit.

Electrical Fan، This device is responsible for forcing circulation of air through the radiator fins to cool, return fuel that goes through the radiator .

Fuel Temperature Sensor, Fuel temperature sensor is a thermometer thermostat compact unite with digital highlight display type, used to detect return fuel temperature and sends a signal to run the fan ON/OFF depending on setting temperature, which can be specified temperature demands.

The exhaust emission analyzer, Analyzer type AIRREX HG-540 was used to measure concentration of exhaust gas emissions inclouded UHC and NO_X **.**

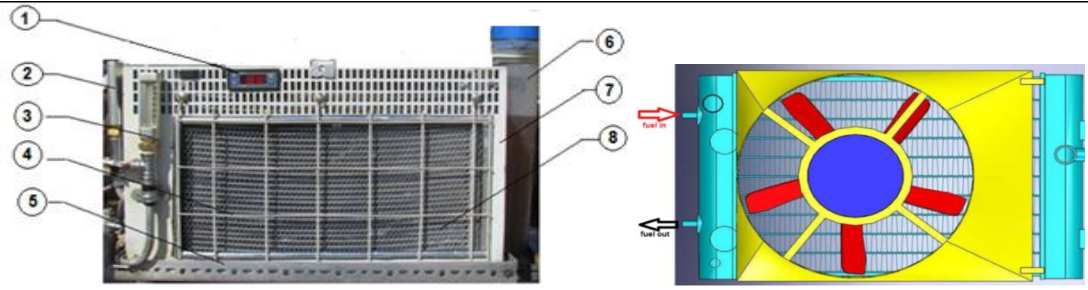
Temperature Control System, The control system is mostly consist of thermometer thermostat as a compact unit, radiator, DC 12V fan and electric circuit components, taking into account aspects such as feasibility of the proposed system. The variables required to implement in this strategy are: (T_{1f}, T_{2f}) inlet and outlet fuel temperature respectively to radiator (heat exchanger) and (*Ta)* ambient temperature. In conjunction with the specific parameters of the system, the control system determines the fuel flow temperature and the correct positioning of the thermostatic sensor actuator (fuel flow that passes through the radiator) to maintain a desired temperature in outlet fuel flow of radiator for supplying injection pump. Therefore three input parameters must be measured to maintain fuel feed forward to control component with selecting fuel temperature. In this work, it would assume that the output fuel temperature via the radiator is approximately equal to the liquid temperature which be entering to fuel injector as shown in figure,(2).

Table 1. Properties of tested fuel

TEST TYPE	VALUES	ASTM TEST
Viscosity @ 40°C	3.8 cst	D445
Viscosity @ 80°C	2.1 cst	D445
Cloud point	-2 °C	D2500
Pour point	-6.7°C	D97
Specific gravity @35°C	0.821	D287
Specific gravity @40°C	0.816	D287
Specific gravity @ 45°C	0.813	D287
Specific gravity @50°C	0.810	D287
Specific gravity @55°C	0.809	D287
Specific gravity @ 60°C	0.807	D287
Specific gravity @ 65°C	0.803	D287
Specific gravity @70°C	0.800	D287
Flash point °C	76°C	

Table 2. Tractor (Anter-71) specifications.

Manufacture model	Anter -71 2WD
Engine type	Zetor, diesel , direct injection,4 cylinder, vertical, four-stroke
Engine cooling	Water
Bore / stroke	102/110 mm
Rated power	(48.117)kW at 2200rpm
Rated speed	2200rpm



A front view **B back view**

1. temperature sensor 2. inlet fuel thermometer 3.fuel temperature outlet device.4. radiator shield 5. fixed frame 6.scaled fuel tank. 7. hard frame 8.radiator core

Figure 1. The Apparatus A front view, B back view

Testing procedure

1- Initially, scaled fuel tank (2 liters) must be filled with pure diesel fuel, run the engine for minimum 10 minutes on idle speed to warming engine up, at the same time preparing exhaust gas analyzer (AIRREX,HG-540) for measuring exhaust gas emission which include (UHC NO_X).

2- Engine speed was increased by control hand lever to 1000rpm and setting fuel temperature control on 40°C, while emission ought to be gained by putting the probe in the tail pipe and printout the results directly from the analyzer. In that moment recording the fuel consumption manually which was determined by measuring the time (*t*) which was taken for the engine to consume a given volume of fuel (20 ml), by stop watch, also recording another parameters which included: exhaust gas temperature, thermometer.

3- Step 2 was repeated, while engine speed was increased to 1500 and 2000 rpm. Then changing fuel temperature to 45 and 50°C, with repeating steps 2, and 3. Every test was repeated three times at different periods of time to check its repeatability, and after making experiments data, engine indicators were analyzed by using the mathematical formulas for the most important elements of performance, as in figure 2.

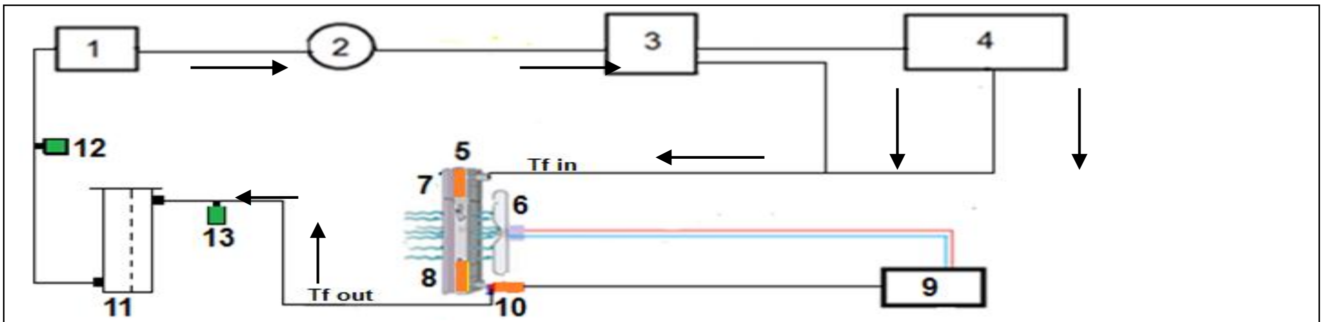


Figure 2.Schematic diagram of experimental setup

1. Preparing fuel pump. 2-Fuel filter. 3.Fuel injection pump. 4. Engine blocks 5.Radiator 6. DC fan [7,13].Thermometer on fuel inlet [8, 12]. Thermometer on fuel outlet. 9- Control unite. 10-Fuel temperature sensor. 11.Scaled fuel tank.

Calculation Equations (Theoretical model)

$m^{\circ}_f = (sg_f * v * 0.001 / t) * 3600$ ……… (1) *(Chaven and Pathak, 2008)*

Where: m°_f *: Fuel Consumption (kg/h).*

sg_f*: specific gravity of the fuel (kg/L).*

V: fuel volume (in milliliter) .

t: Time taken for the engine to consume a given volume of fuel (sec).

$q = \dot{M}_f * C_P * \Delta T$ ……(2)

$\dot{M}_f * C_{Pf} * \Delta T_f = \dot{M}_a * C_{Pa} * \Delta T_a$……….. (3) *(Balance of Energy)*

q=heat in Joel.

$\dot{M}_f$*= fuel mass flow rate kg\sec* $\dot{M}_a$*=Air mass flow rate kg\sec*

C_{Pf}*=fuel specific heat kJ/kg. °C* C_{Pa}*=Air specific heat KJ/kg .°C*

T_f *= Tfuel,* T_a *= Tair*

$\Delta T_f = (T_{2f} - T_{1f})$ $\Delta Ta = (T_{2a} - T_{1a})$

$\dot{M}_f = q * p$ …… (4)

$q_f = \dot{M}_f * C_{Pf} * \Delta T_f$……..(5)

$q_a = \dot{M}_a * C_{Pa} * \Delta T_a$……(6)

$q_f = q_a$……..(7) (JMES, 2012 and Holman J.P, 1986)

Results and Discussion

Experimental study of engine performance parameters and emissions characteristics of diesel engine at different engine speeds and fuel temperatures have been performed the results can be summarized as below.

Fuel consumption kg/h:

Figure (3) illustrates the effect of inlet fuel temperature on fuel consumption, It was observed that fuel consumption increased with increasing inlet fuel temperature at variant engine speeds (1000, 1500, 2000 rpm), noticed that, fuel at 50°C recorded the higher rate 3.077kg/h of fuel consumption FC, followed by fuel at 45°C 2.980 kg/h, while fuel at 40°C recorded the lower rate 2.55kg/h of FC for all speeds. The reason may be that, the higher fuel temperature tends to produce higher injection pressure ,while the fuel temperature is increased, the fuel density is decreased therefore ,a higher injection pressure is required to gain an equal fuel mass in order to produce the same require brake power (torque), that cause to increase engine fuel consumption. (3, 6, 11)

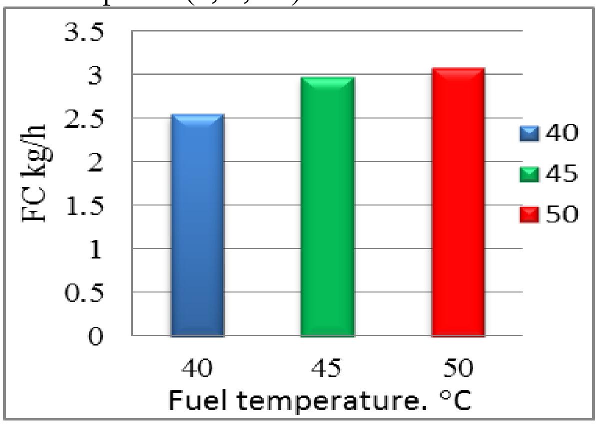


Figure 3 :.Effect of Fuel Temperature on Fuel consumption

Results obtained from the figure 4 showed that engine speed has an influence on fuel consumption FC, engine at speed.2000 rpm registered higher rate 4.133 kg/h of FC, followed by fuel at speed of 1500 recorded 3.260 kg/h and observed the lower rate 1.633 kg/h of fuel consumption FC was at 1000 rpm for all fuel temperatures. To maintain engine power requires increase speed which means inject more quantity of fuel, thereby generating heat and power [3].

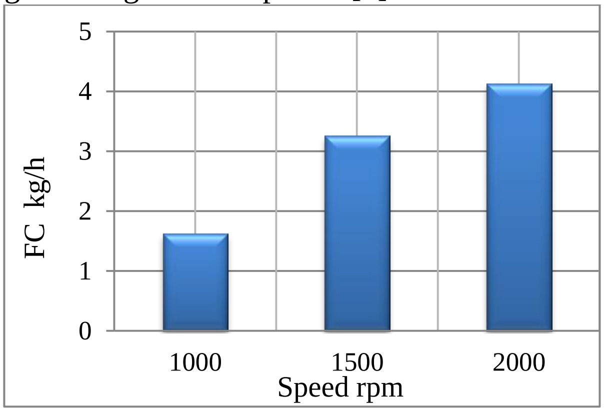


Figure 4 :.Effect of Fuel Engine Speed on Fuel consumption

Exhaust Gas Temperature EGT (°C) The variation of Exhaust Gas Temperature EGT with fuel temperatures and speeds can be seen in the figure 5,6 when fuel temperature increased, to 50°C EGT recorded 143.2°C, followed by fuel at 45°C 133.7°C, while fuel at 40°C registered lower rate 133.3°C of exhaust gas temperature for all speeds. These variation in EGT, due to that higher fuel density and viscosity represented mean effective factor for decreasing fuel consumption therefore ,the difference between fuel densities effect on fuel consumption so maximum fuel consumption amount can be expected with low fuel density, this result cause to increase EGT due to burned more fuel. (9).

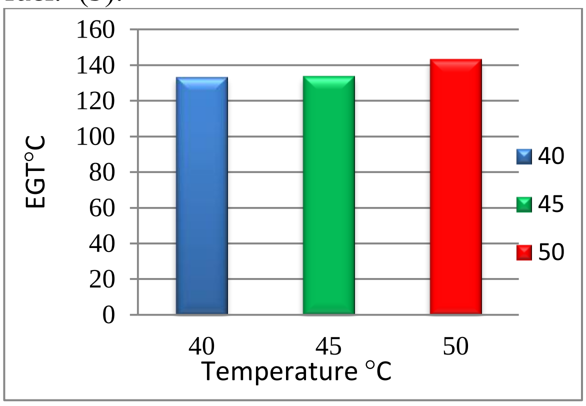


Figure 5 :.Effect of Fuel Temperature on EGT

The variations of EGT for different speeds are given in figure 4 which showed that EGT was affected by engine speed, The higher rate 148.7°C of EGT was recorded at 2000 rpm followed by engine running speed 1500 rpm that registered 137.7°C of EGT, while the lower rate 129.5°C of EGT was recorded at

1000 rpm for all fuel temperatures. The reason might be the rise of EGT with increasing of the speed due to inject more quantity of fuel, thereby generating heat and power resulting from the combustion of fuel, in addition to the various exhaust products as well as increasing friction between the moving engine parts. (12, 15).

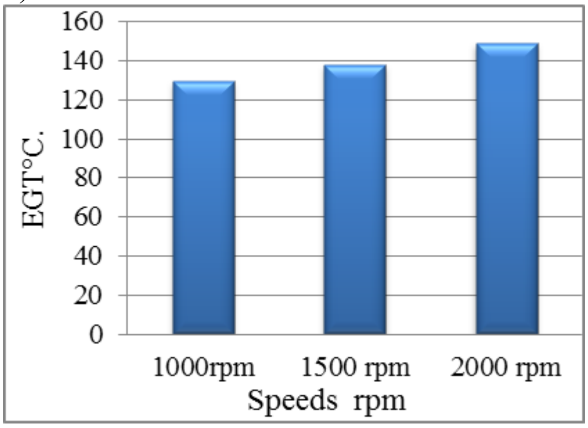


Figure 6 :.Effect of Engine Speed on EGT

Un-burnt Hydrocarbons HC (ppm):

The variation of Unburnt Hydrocarbons UHC for different fuel temperatures and speeds are given in figure 7, as can be seen the higher values 25.971ppm of UHC emission was registered when fuel temperature at 50°C 25.971, followed by fuel at 45°C 21.611 ppm, while fuel at 40°C recorded the lower rate 19.086 ppm of UHC, for all speeds. The reason of these variation may be due to high density and viscosity of fuel at low temperature that reduces pump leakage which cause increasing in injection pressure and that caused on excellent fuel air mixing in combustion chamber, and consequently reduced the concentration of UHC (7).

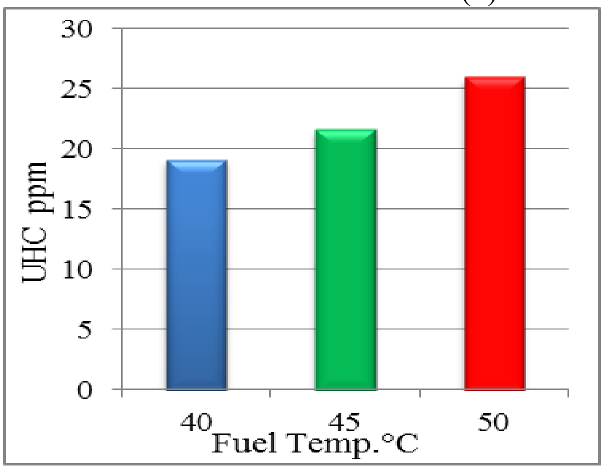


Figure 7 :.Effect of Fuel Temperature on UHC

Figure 8 showed that engine speed has an influence on UHC. Engine at speed 2000 rpm registered higher rate 36.996 ppm of UHC, followed by engine speed of 1500rpm, while the lower rate 14.165ppm was gained at 1000 rpm, for all fuel temperatures. The reason may be at high speed there is a shortage in quantity of air to mix with fuel and that may be caused incomplete consumption of fuel, consequently produce UHC emission. (7).

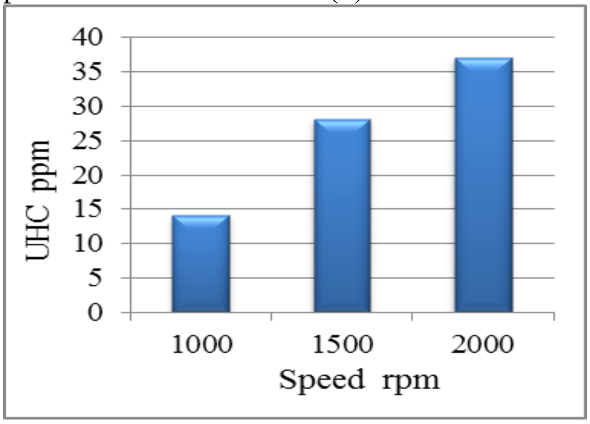


Figure 8 :.Effect of Engine Speed on UHC

Nitrogen Oxide NOx (ppm)

The variation of Nitrogen Oxide (ppm) with deferent fuel temperatures, and speeds are given in figures 9, 10. From figure 9 noticed that, fuel at 50°C recorded the higher rate 139.333ppm of NOx followed by fuel at 45°C 134.722ppm, while fuel at 40°C recorded the lower rate 128.667 ppm of NOx., for all speeds . The reason might be NOx emission is directly linked to the combustion temperature; rise in the combustion temperature increases the NO_x concentrations in the exhaust gas. In diesel engines NOx formation is highly temperature dependent phenomenon and takes place when the temperature in the combustion chamber was increased. (7, 8).

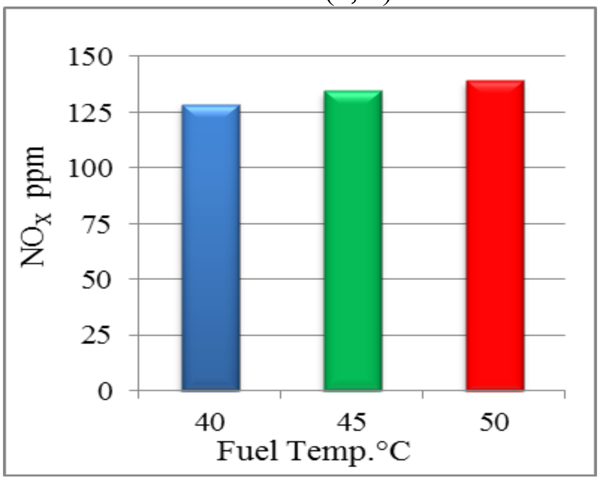


Figure 9 :.Effect of Fuel Temperature on NO_x

Figure 10 showed the effect of engine speed on NO_x . It has been seen that, the rate of NO_x increased as engine speed increased. The higher rate of NOx was 159.165ppm at higher speed of 2000 rpm, while the lower rate 111.411ppm at speed of 1000 rpm for all fuel temperature. The reason of increasing NO_x at high speed may be due to increase the friction and consequently increased the temperature of cylinder wall, which caused to formation of NO_x .

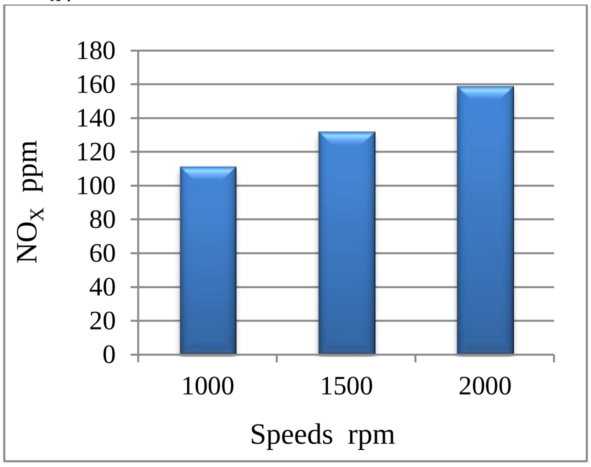


Figure 10 :.Effect of Engine Speed on NO_x

Conclusion and Recommendations

Conclusions

From the above results, the conclusions can be as followed test it with temperature ranging from 40-50 °C

1. fuel at temperature 40°C recorded lower rate 2.551 kg/h of fuel Consumption FC, for all speeds companied with fuel inlet temperature 45, 50°C.
2. There is a significant effect of fuel temperature on exhaust gas emission, so exhaust gas temperature was recorded 133.3°C for fuel inlet temperature of 40°C.
3. The dual interaction between fuel temperature 40°C and engine speed of 1000rpm, recorded lower values of fuel unburned hydrocarbon UHC, nitrogen oxide.
4. Better ranging of fuel temperature was 40°C because it has no significant effect on fuel. Consumption FC. Exhaust gas temperature EGT.

Recommendations:

Recommendations can be as followed:

1. Using fuel with 40°C and engine speed at rate 1000rpm should be adopted.
2. Repeat this experiment with fuel temperatures at high rates (more than 50°C) to find out its influence on engine performance and emission.
3. Test deferent diesel fuel types (deferent fuel sources) with deferent temperatures to clarify its effect on engine performance.

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