AENSI Journals

Australian Journal of Basic and Applied Sciences

ISSN:1991-8178

Journal home page: www.ajbasweb.com

An Experimental Study on Combine Effect of Exhaust Gas Recirculation (EGR) and Inlet Air Temperature on Emissions of Diesel Engine in Iraq with Using Daura Fuel

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ARTICLE INFO

Article history:
Received 8 August 2014
Received in revised form
12 September 2014
Accepted 25 September 2014
Available online 2 November 2014

Keywords:
Exhaust gas recirculation, Diesel engine, Inlet air temperature, Emission.

ABSTRACT

Concern of environmental pollution and energy crisis all over the world have caused the research attention on reduction of diesel engine exhaust emissions and saving of energy simultaneously. Better fuel economy and higher power with lower maintenance cost has increased the popularity of diesel engine vehicles. Diesel engines are used for bulk movement of goods, powering stationary/mobile equipment, and to generate electricity more economically than any other device in this size range. As we know that the diesel engine are known for their high NO_X formation and Exhaust Gas Recirculation (EGR) is being used widely to reduce and control the oxides of nitrogen (NO_X) emission from diesel engines. EGR controls the NO_X because it lowers oxygen concentration and flame temperature of the working fluid in the combustion chamber. By using heating intake air it was concluded that decreasing the **CO** with 12% and the **HC** with 35% with 30C°of intake air temperature , However. In this study it was concluded that using **EGR** with rate 15% and uniform inlet temperature (30 C °) reduced the **NO_X**47.4%

To Cite This Article: Dr. Jamal H. Waheb and Eng. Mohanad Hatem Fezea., An Experimental Study on Combine Effect of Exhaust Gas Recirculation (EGR) and Inlet Air Temperature on Emissions of Diesel Engine in Iraq with Using Daura Fuel. ***Aust. J. Basic & Appl. Sci., 8(16): 274-281, 2014***

INTRODUCTION

Nitrous Oxides (NO_X for short) are one of the most harmful pollutants produced by automobiles, damaging the ozone layer and the environment. Hence, countries like U.S, Japan and those in the European Union have come up with more stringent emission norms to reduce the impact on the environment (ERN SHER). Serious efforts are being made to reduce the amount of NO_X emitted by automobiles, especially those using Diesel Engines. There are many techniques available to reduce $NO_{X,}$ Retardation of Injection timing, Exhaust Gas Recirculation (EGR) and Selective Catalytic Reduction (SCR). SCR is the most effective technique, but it is currently difficult to implement on existing cars and trucks due to the extensive modification that must be done to the exhaust system and the prohibitive cost of the technique (SIMON REIFARTH). Retarding the injection timing reduces engine fuel-efficiency and power output while increasing soot and HC emissions and is hence is not favored (Ming Zheng *et al*.,). EGR is a cheap and easily implemented option. Many people have studied the effects of intake air dilution using EGR and other gases like N_2 by conducting tests in steady-flow combustors, gas turbines and diesel engines. It has been that a strong correlation exists between the stoichiometric-adiabatic flame temperature of the diesel diffusion flame and NO_X emissions. This has also been confirmed by many other studies (David Powell, J.,).

The purpose of this study was to use this correlation to predict the amount by which EGR will reduce NO_X emissions, without actually installing an EGR system and conducting experiments. The technique uses only already available Figure(1), base-engine data like air-fuel ratio, NO_X emission, etc. for different speeds and loads and predicts what the reduction in NO_X will be for different rates of EGR flow (Jaffar Hussain, K. *et al*., 2012).

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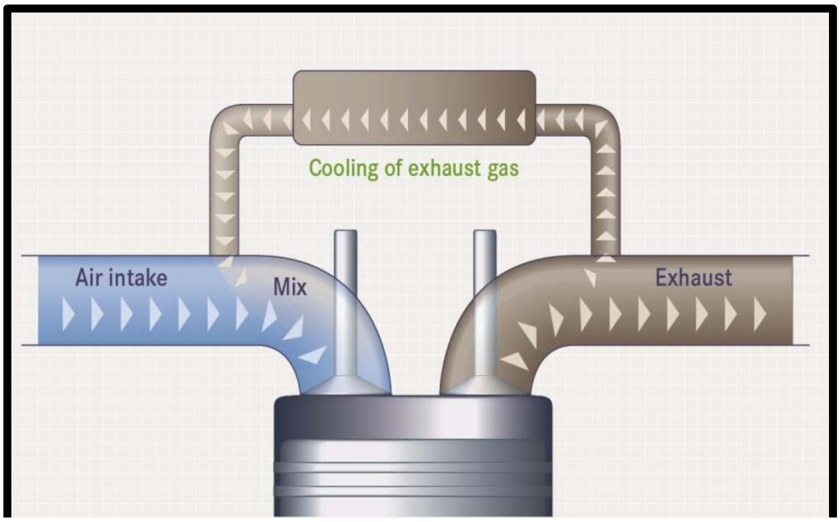


Fig. 1: EGR technique

This will help the engine manufacturer to estimate quickly whether EGR implementation will serve to reduce NO_X emissions sufficiently for a particular engine. This procedure may also help in optimizing the EGR-valve control-system quickly by providing it with a set of good start-values for EGR flow rate for different speeds and loads (Arjum Krishnan, Vinay C., *et al*.,).

The first prevents emission formation in the engine cylinder through the use of improve combustion technologies, such as heat intake air system, low compression ratio bowls ,and exhaust gas recirculation (EGR).The second uses purifying devices, such as diesel particulate filters (**DPFs)** and lean NO_X (Abd-Alla, G H., 2002).

Theoretical analysis:

Exhaust gas recirculation is an effective and simple means to control NO_X emissions by lowering combustion temperature and reducing oxygen concentrations in the intake air. EGR involves replacement of oxygen and nitrogen of fresh air entering in the combustion chamber with the carbon dioxide and water vapor from the engine exhaust (Abd-Alla, G H., 2002). However, EGR results in increasing the UHC and CO emissions, with the observed outcome of reduction in NO_X emissions. EGR rate was calculated employing equation (1). Flow rates of recirculated gas and inlet air charge was measured with the help of rot meters, which give us the amount of EGR in unit L/h.

$$\%\ EGR = \frac{\text{Volume flow rate of EGR}}{\text{Volume flow rate of charge into the cylinder}} \times 100 \quad (1)$$

First we have the value of air volume and fuel volume according to the equation (2) and (3).

$$\dot{m}_{air} = Cd\ \frac{\pi d^2}{4}\sqrt{\frac{2p\Delta p}{RT}} \quad (2)$$

Cd=0.6,d:Orifice Diameter =0.0185m (User guide of TD212)**]**

R=287

P: Ambient Pressure

$$\dot{m}_f = \frac{V_f \times \rho_{fuel}}{t_b} \quad (3)$$

Where:

$\dot{m}_f$ = volume of fuel consumption in (kg/sec).

V_f = fuel flow rate in the device of engine consumption which = $8 \times 10^{-6}\ m^3$

ρ_{fuel} = specific mass of the fuel in (kg/ m³).

t_b = time of fuel consumption in second .

Indicated power (I.p),kW:

$$I.p = \frac{I_{mep} \times Vb \times K \times N}{n \times 60} \quad (4)$$

Where:

I_{mep} : indicated mean effective pressure in kN/m^2

V_b:Engine Capacity =0.000232 m³

K: number of cylinders=1.
n: 2 for 4 – strokes.
N: revolution speed, rpm.

Brake power (b.p), kW:

$$b.P = \frac{T \times 2\pi \times N}{60 * 1000} \quad (5)$$

Where:
T = 6Nm , N = 2100 rpm

Brake specific fuel consumption (B.S.F.C) $\frac{g}{kW.hr}$:

$$B.S.F.C = \frac{\dot{m}_f}{b.p} \quad (6)$$

Indicated thermal efficiency η_{Ith}, %; (WILLLARD, W., PULKRABEK):

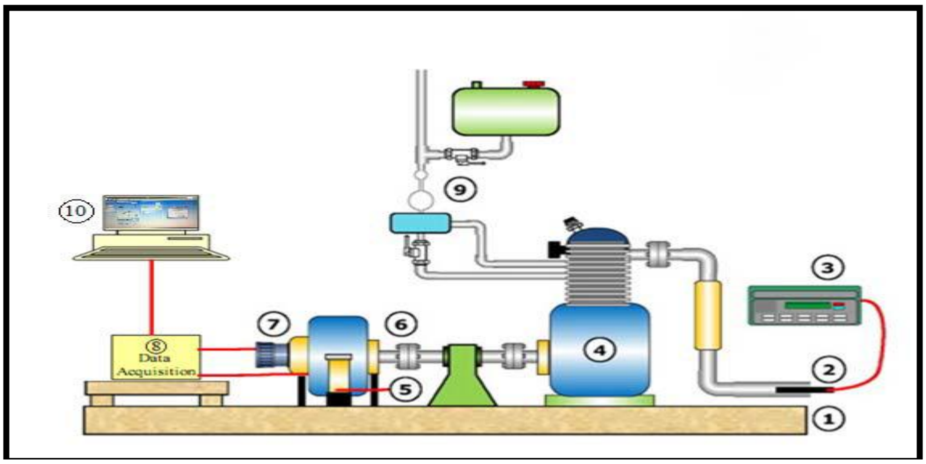
$$\eta_{Ith}\,\% = \frac{I.p}{L.C.V * \dot{m}_f} \quad (7)$$

Where:
L.C.V = fuel lower calorific value=43800 kJ/kg this value is taken from the Laboratory of Daura Filtered in Iraq.

Experimental work:

Three cases were taken in this study with constant engine speed 2100rpm.and constant Torque 6 Nm with variable EGR percentage 0%, 5%, 10%and 15%, and variable intake air temperature (normal, 20Cº, 30Cº and 40 Cº) and make comparison with the normal state and study how to choose the perfect state .Two factors were studied in this experiment included (EGR percentage and intake air temperature) these were follow:

1. EGR 5% and with intake air variable temperature (20Cº, 30 Cº and 40 Cº).
2. EGR 10% and with intake air variable temperature (20Cº, 30 Cº and 40 Cº).
3. EGR 15% and with intake air variable temperature (20Cº, 30 Cº and 40 Cº).



1- Engine chassis 2- exhaust gas analyzing probe 3- exhaust gas analyzer 4- single cylinder diesel engine 5- load cell 6- dynamometer 7- tachometer 8- Data Acquisition 9- fuel burette 10- computer.

Schematic Diagram For The Rig Instrumentation:

Table 1: Technical specifications of the engine. (User guide of TD212)

Item	Specification
Engine Manufacturer	TQ TD 212, UK
Fuel Type	Diesel
Maximum Power	3.5kW at 3600 rev/min
Maximum Torque	16 Nm at 3600 rev/min
Bore	69 mm
Connecting Rod Length	104 mm
Engine Capacity	232 cm3
Compression Ratio	22:1
Oil Type	Multigrade SAE 5W-40

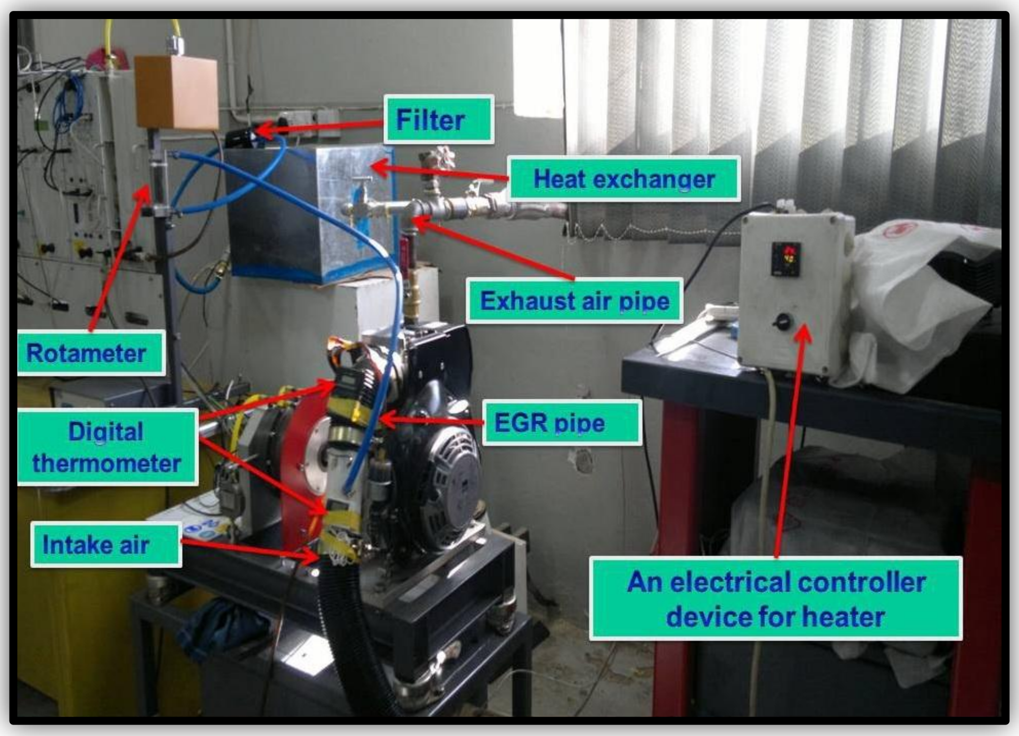


Fig. 2: the test rig instruments

Figure (2) shows the rig which we used it in our experimental at the internal combustion engine laboratory – department of machines and equipment Baghdad Technology Institute from October 2013 to February 2014.and at ambient air room at 16 Cº. It was used the Rota meter to measure the value of EGR flow rate (L/h),

It was used heat exchanger with this rig because we can't measure the value of exhaust air which its temperature up to 300Cº and the maximum temperature of Rota meter doesn't exceed100Cº, and it was used an electrical device control to manage the air heating temperature by using tow heaters (1500w) and fixed them on the intake air box as show in figure (3)

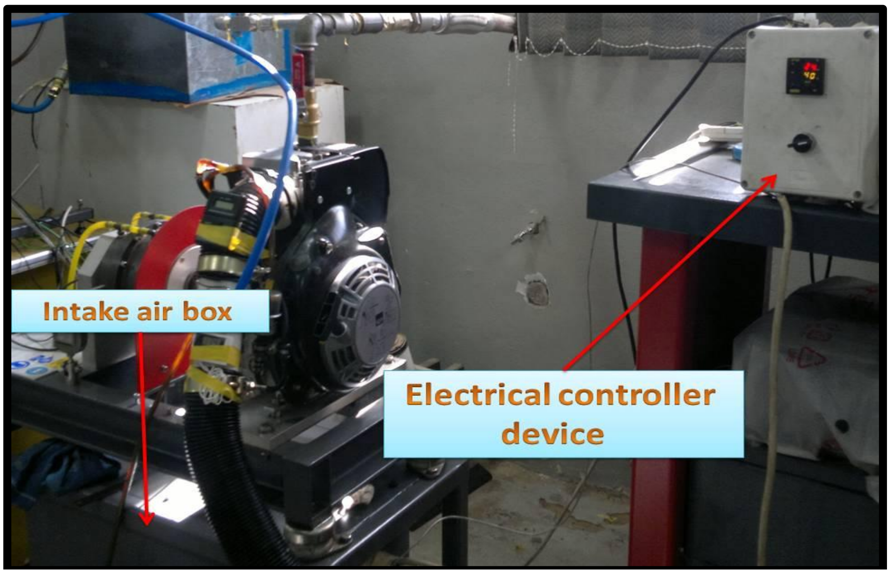


Fig. 3: Electrical controller device

RESULTS AND DISCUSSION

Figure (4) shows the relation between the indicated thermal efficiency (%) with the EGR rates at constant engine speed 2100rpm and torque of 6 Nm and variable intake air temperature. It was conclude that the indicated thermal efficiency is increase with the EGR rates and heated air intake except the experiment at 40Cº intake air temperature, it give us bad results and the best experiment at 30 Cº intake air temperature.

Figure (5) represents contrast of BSFC for engine speed 2100 rpm at torque 6 Nm using EGR with baseline data .BSFC is lower at the low EGR rate. However, at this case BSFC with EGR is almost similar to that of without EGR (blue line) except the experiment at 40 Cº, it gave us low value of BSFC with increasing EGR rate.

Figure (6) shows the main benefit of EGR in reducing NO_X at engine speed 2100 rpm, torque 6Nm and variable air intake temperature the reason from using EGR technique for reducing NO_X in emissions of diesel engine it reduced the oxygen concentration and decreased the flame temperatures in the combustion mixture.

Effect of EGR on unburned hydrocarbon (HC) and carbon and carbon monoxide (CO) are shown in Figures (7) and (8) respectively. These graphs show that HC and CO emissions increase with increasing EGR but it decrease with intake air temperature increasing, lower excess oxygen concentration results in rich air- fuel mixture at different locations inside the combustion chamber .This heterogeneous mixture dose not combust completely and results in hydrocarbons, and carbon monoxide emission.

It was found that thermal efficiency is slightly increased and BSFC, but at high rate of EGR are similar with EGR than without EGR. Exhaust gas temperature is decreased with EGR and smoke capacity, Hydrocarbons and carbon monoxide are increased with EGR, but NO_X emission decreased significantly.

Figure (9) explain the relationship between air fuel equivalence ratios with EGR rates, at torque 6Nm. The equivalence ratio increasing slightly, the case of 20C˚ recorded the highest value followed by the case of 30C˚ and the others, the reason may be due to volume of air drawn into the engine (the swept volumes of cylinder), which increasing with EGR& intake air temperature.

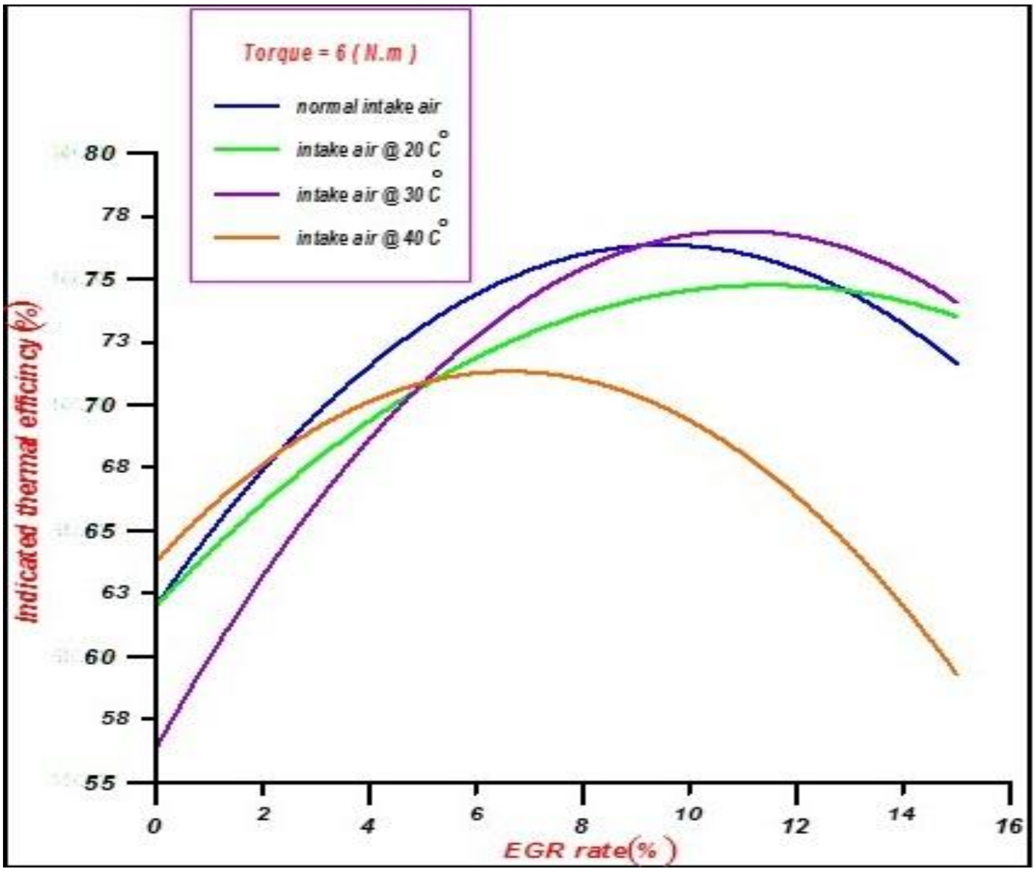


Fig. 4: indicated thermal efficiency for different EGR rates

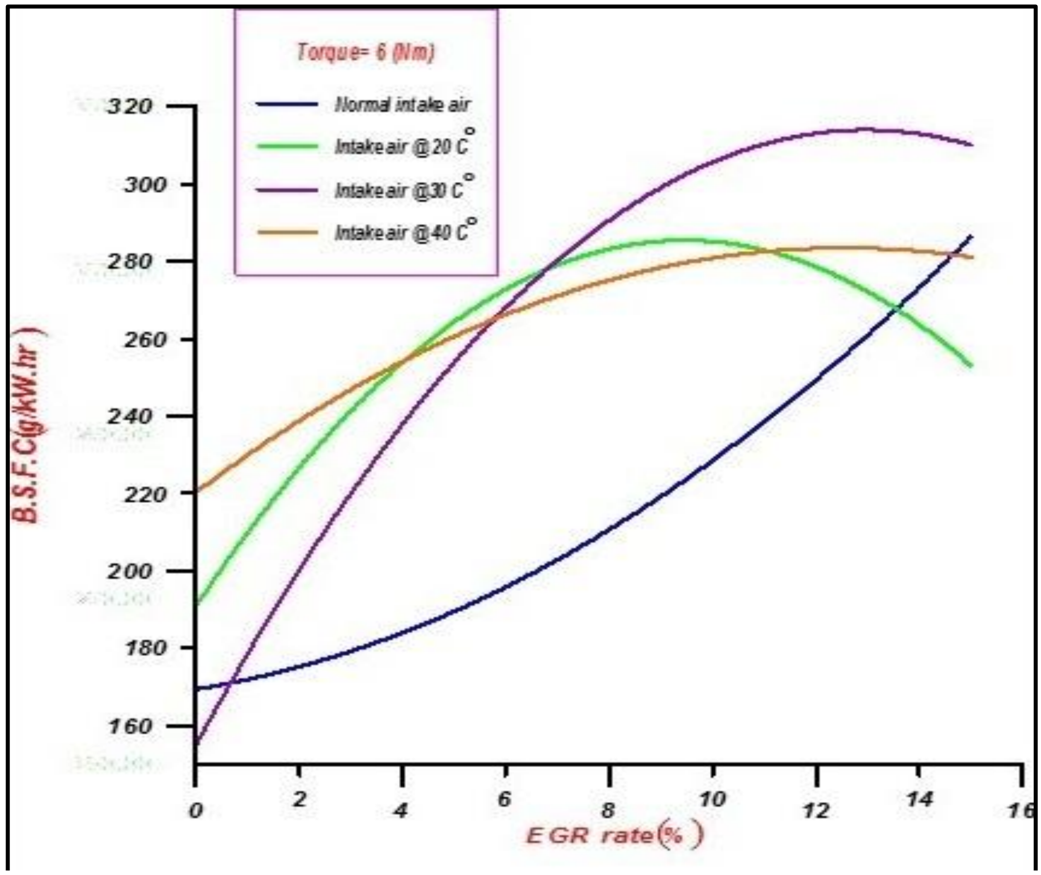


Fig. 5: Brake specific fuel consumption for different EGR rates.

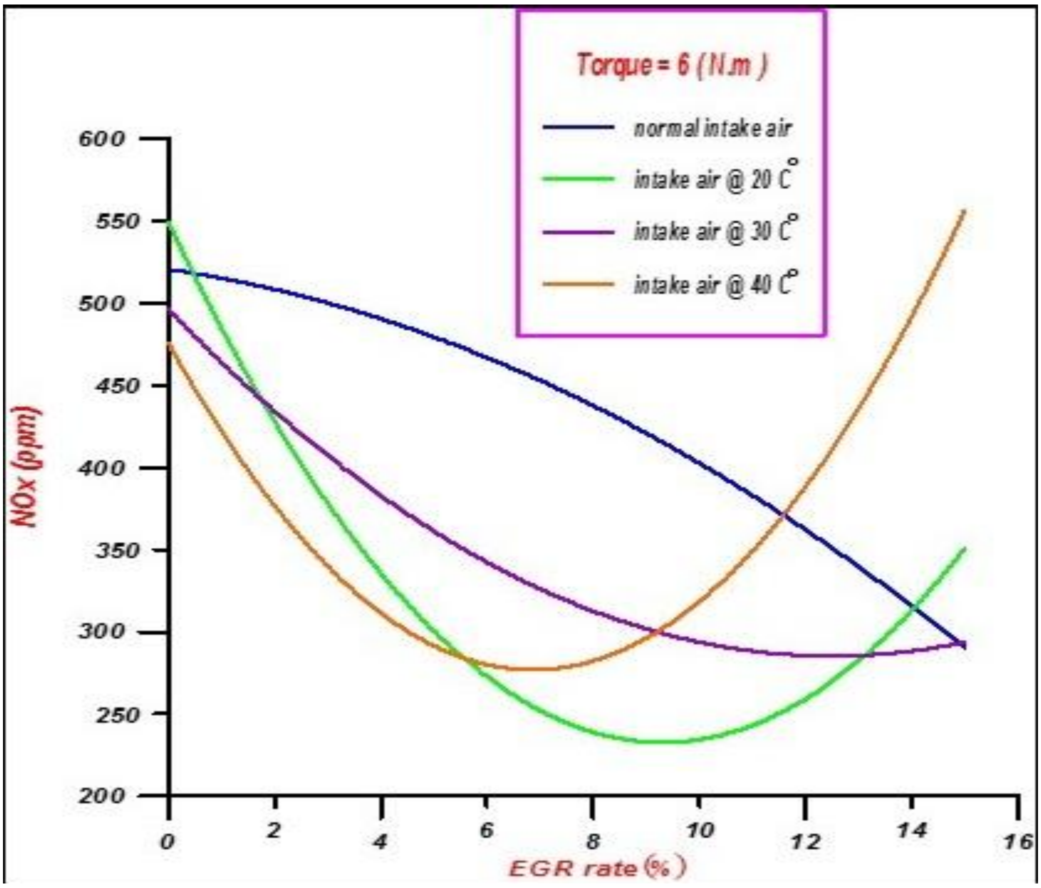


Fig. 6: NO_X for different EGR rates

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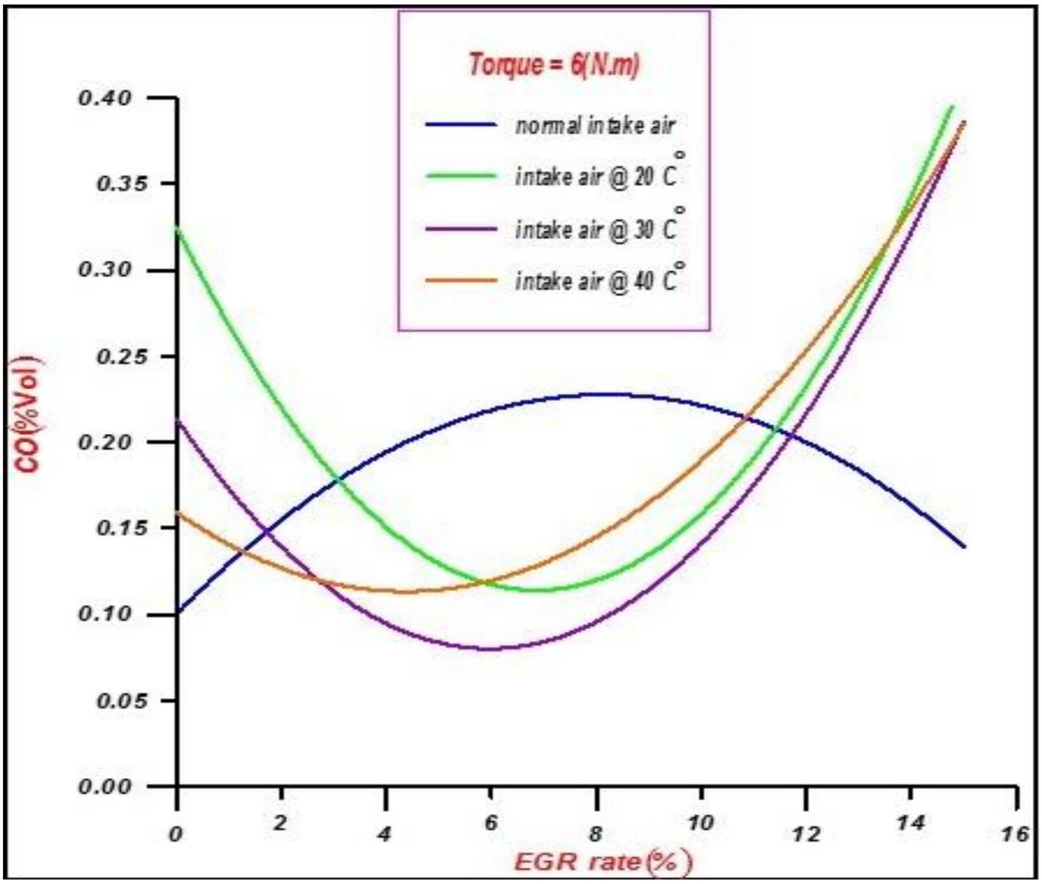

Fig. 7: carbon monoxide with EGR rates

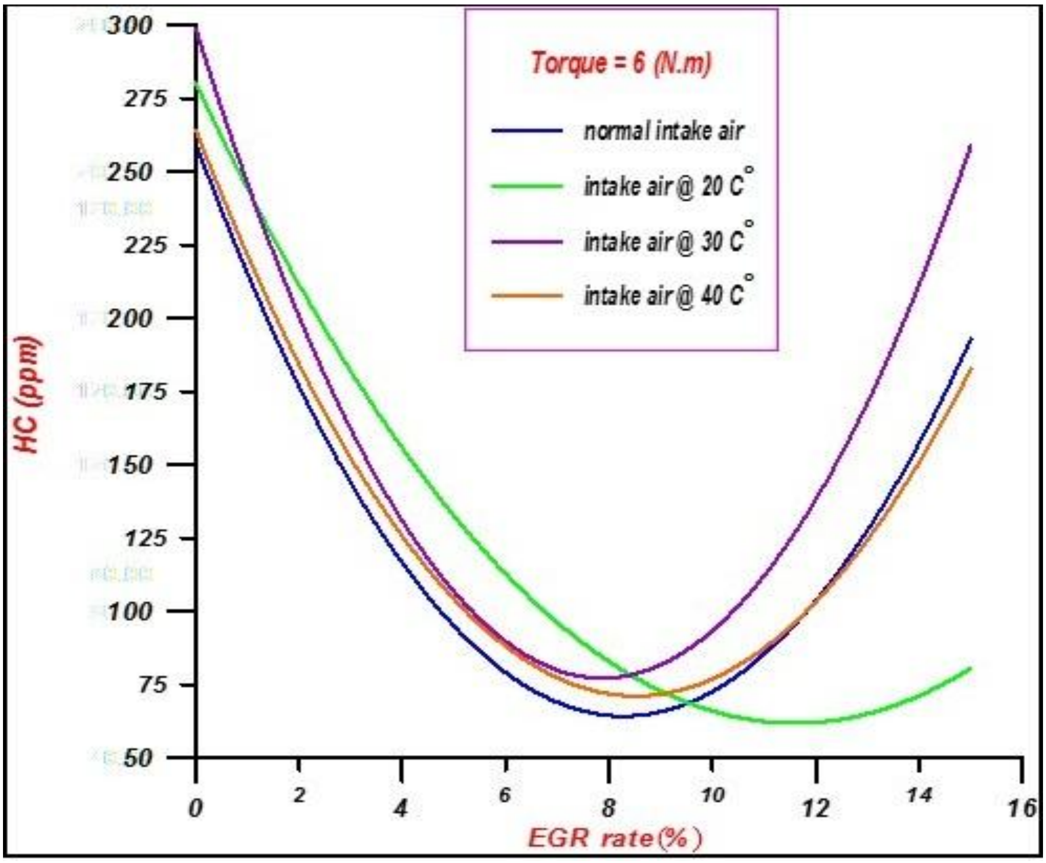

Fig. 8: hydrocarbons with EGR rates

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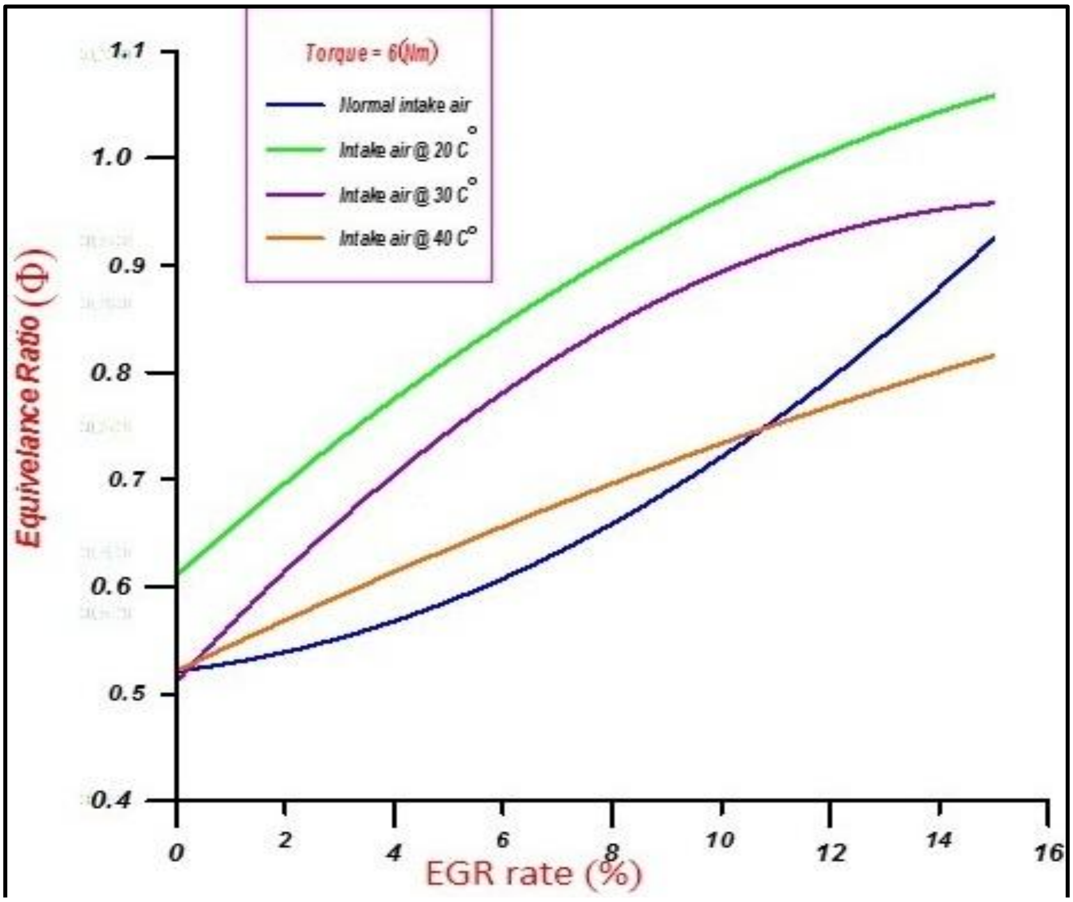

Fig. 9: air fuel equivalence ratio with EGR rates

Conclusion:

From this work it was concluded that EGR is a very useful technique for reducing the NO_X emission. EGR displaces oxygen in the intake air and dilute the intake charge by exhaust gas recirculated to the combustion chamber. Recirculated exhaust gas lower the oxygen concentration in combustion chamber and increase the specific heat of the intake air mixture, which results in lower flame temperatures.

It was observed that 15% EGR rate and intake air temperature at **30 Cº** is found to be effective to reduce NO_X emission 47.4% substantially without deteriorating engine, and reduce the **CO** concentration with 12% ,the percentage reduction of **HC** reached to 35% if it compare with the normal steady state.

It can be concluded that the experiment has a benefit to reduce the most danger emissions gases (**NO_X, HC** and **CO**) together and no experiment has done this work in Iraq.

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