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The Performance of Exhaust Gas Recirculation (EGR) on a Single-Cylinder Diesel Engine Fueled B10 Biodiesel and Diesel

Mohamed Hussin Abdullah Altaher

Faculty of Science and Technology Om-Alaranib, Om-Alaranib College of Science & Technology, Libya

Abstract: ***Increasing global population in present years means more vehicle ownership which leads to the increasing of oxides of nitrogen (NOx) and greenhouse gas emission. Oxides of nitrogen (NOx) are produced from the fuels which burned at high temperatures; contributes to the formation of ozone smog, harmful unseen particles, acid rain, and oxygen depletion that reduced the water quality. The use of higher oxygenated nature biodiesel as an alternative fuel also contributes to the increasing formation levels of NOx emission. In respond to the matters arise, exhaust gas recirculation (EGR) has been introduced to control NOx emissions from diesel engines effectively which lower the oxygen concentration in the combustion chamber. Experiments will carry out by implementing EGR consisting a non-insulated stainless steel pipe together with an industrial grade ball valve on a 219 cc single cylinder four- stroke Yanmar L48N diesel engine. An effort has been taken to study the performance and emission characteristics of a diesel engine fueled with biodiesel and diesel fuel using EGR. All the experiments were conducted on a single-cylinder. Palm-biodiesel blends will use as a baseline fuel. The objective is to understand the effect of EGR on diesel engine performance and emissions levels of NO in particular, C0, C02, and HC contained in exhaust gas. The engine will operate at an increasing engine speed from 1200rpm up to 3000rpm and significant data such as power, torque and exhaust gas emission levels its record at various EGR loads. The EGR flow rate will be regulated using the ball valve. The results obtained with biodiesel (B10) were compared with the diesel fuel as reference fuel. The engine performance and efficiency obtained in biodiesel case were less, which could be attributed to the lower calorific value of biodiesel. CO and UHC emissions for biodiesel were lower than that of diesel fuel. However, it was observed that NOx emissions for biodiesel were higher than that of diesel fuel. Exhaust gas recirculation (EGR) is a very effective technique to reduce NOx emissions from a diesel engine. Objective of this research paper is the fabricate the EGR line for single cylinder diesel engine, engine performance (power and torque) for the different EGR opening and investigate the effect of Exhaust Gas Recirculation (EGR) on the emissions levels of palm-biodiesel B10 and diesel.***

Keywords: Exhaust gas recirculation. Diesel engine, Bio-Diesel, Fuel, renewable fuel

1. Introduction

Current energy policies are greatly reliant on fossil energy. Fossil fuels are the greatest energy source among all energy resources. The major part of energy requirements in the world is provided thorough fossil fuels such as petroleum, natural gas, oil and coal. Due to resource limitations, it is expected that the rising demand and diminishing supply will affect global fuel prices dramatically. Over time fuel prices are significantly volatile. Besides rapid rate of energy demand, the trend of the global crude oil price is also sensitive to many external factors such as political propaganda, currency fluctuation, and demand in supplies. The declining reserve of fossil fuels, and more importantly, the high fuel prices have strongly motivated the search for alternative engine fuels. For diesel engines, a great deal of research effort has been oriented toward using biodiesel as an alternative fuel for land transport and power generation. The use of diesel engines reduces emissions and improves fuel consumptions. Diesel machines are widely used in heavy-duty applications especially in construction and farming sectors. Accordingly, the rate of reduction of diesel fuel is the greatest among gasoline fuels, which subsequently results in the greater price of diesel fuel than other gasoline fuels due to increased demand. Additionally, the growing concern about environmental pollution since the 1990s has boosted the interest in substitute fuels. This has led to extended efforts and financial supports for research studies in energy management and conservation. Recently, the issues of steadily rising fuel prices, declining oil storage and air contamination have resulted in the investigation of fossil fuel substitutes. The increase in greenhouse gases such as CO2 which is causing climate change and global warming coupled with the fossil fuels decreasing reserves as well as increasing prices of fuel have robustly boosted the interest in making use of biodiesel for power generation. The term “Biodiesel” refers to Fatty acid methyl esters. These esters are often created from animal fats or extracted from vegetables and have acceptable capabilities to be used in diesel engines. Because diesel fuel and vegetable oils have close cetane numbers, biodiesel made from vegetable oils might be used in current diesel engines after minor alterations. One of the considerable alternative renewable fuel sources is vegetable oils which have similar combustion characteristics and physicochemical properties to the petroleum diesel. many researchers had well-documented their reports on the study of the vegetable oils on their properties and their effects on the engine performances and exhaust the selection of vegetable oils mainly based on geography and climate condition where such as corn, soybean, peanut, rapeseed, canola and olive mostly planted in Europe and United States, while in Asia, South America and Africa preferred for palm oil, coconut, jathropa as well as rubber seed. These vegetable oils have several advantages include low level of sulfur, higher oxygenated nature, and higher cetane number and produce less toxic emission when they are burned). These crop oils have a better lubrication and a higher ignition temperature which not very flammable (LR). There were great potentials for the vegetable oils to be discovered in terms of engine performance and exhaust emission. Reported that both intake oxygen enrichment and biodiesel fuel which higher oxygenated nature increase NOx emissions. They also concluded that the increase was higher when more oxygen is used during combustion rather than oxygenated fuels were used the oxygen content of biodiesel could not cause any increase in NOx formation because the combustion flow occurs in the oxygen-fuel ratio region around the stoichiometric one, which is normally around 3.58 for a standard diesel fuel and 2.81 for typical biodiesel fuels. Exhaust gas recirculation is the effective way to control the NOx formation; where reducing the exhaust temperature during combustion. That there is a vast reduction in NOx emission but slight increasing in bsfc and smoke density concentration corresponding to the higher EGR rate. The effect of biodiesel on a four stroke DI diesel engine fueled with sunflower methyl ester (SFME) employing the EGR technique. They reported that there is a reduction in 25% less NOx emission at the same level smoke emissions with 15% GER rate.

2. Problem Statement

The growing economic risk of relying primarily on fossil fuels with limited reserves and increasing prices has increased the interest in alternative energy sources. Clean and renewable biofuels have been touted as the answer to the issue of diminishing fossil fuels. Biodiesel is an alternative fuel that receiving a lot of attention nowadays due to its availability sources and renewability. The source of biodiesel may be divided into two categories; vegetable oils and animal fats. However, vegetable oils have become the main actor in producing biodiesel such as soybean oil, raw rapeseed oil, waste cooking oil, cottonseed oil, sunflower oil, crude palm oil and much more. The usage of this vegetable oil is due to the great fuel properties such as flash point and acid value that comparable to the diesel fuel. Increasing global population in present years means more vehicle ownership which leads to the increasing of oxides of nitrogen (NOx) and greenhouse gas emission. Oxides of nitrogen (NOx) are produced from the fuels which burned at high temperatures; contributes to the formation of ozone smog, harmful unseen particles, acid rain, and oxygen depletion that reduced the water quality. The use of higher oxygenated nature Palm oil biodiesel as an alternative fuel also contributes to the increasing formation levels of NOx emission. However, dominant emissions trends are usually an increase in oxides of nitrogen, and decreases in carbon monoxide, particulate matter, unburned hydrocarbons and aromatics. Changes in emissions of carbonyl compounds are less certain, by introducing exhaust gas recirculation (EGR) into diesel engine system. EGR recirculates exhaust gas back into the engine cylinder.

In project research, the effect of Exhaust Gas Recirculation (EGR) on the performance and emissions of a single cylinder naturally aspirated constant speed diesel engine. At first, the performance of the engine was evaluated with the selected palm biodiesel blends.

3. EGR Setup

This project focuses on the determining the optimum amount of EGR which will show the best engine performance and the cleanest exhaust gas emission with the lowest NO. In order to perform the experiment as mentioned, an external stainless steel pipe with a diameter of 25mm will be connected from the engine's exhaust manifold up to the air intake manifold. A ball valve will be used to regulate the amount of exhaust gas re-circulated back into the air intake manifold and the amount of exhaust gas to be discharged out.

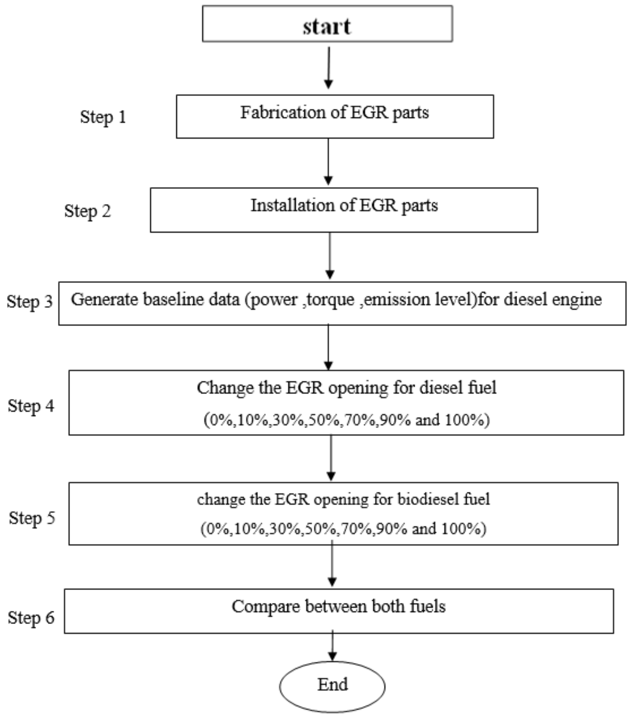

Figure 1: Flowchart of EGR

For this project, it is important to ensure that EGR flow components, ducts and valves, capable of withstanding the boost pressure (commonly 1–2 bar gauge pressure) whilst being leak free. The EGR pipe should also be resistant to extreme exhaust temperatures that are commonly in a range of 100°C to 600°C. The duct should be made of aflexible structure such as stainless steel bellows in order to absorb the thermal expansion, withstand high pressure and tolerate mechanical vibration. The figure 3.6 shown computer aided drawing (CAD) of EGR setup .The valve was fixed with apipe on asingle cylinder diesel engine.

Figure 2: 3D computer aided drawing (CAD) of EGR setup

3.1 EGR Control Valve

In order to control the EGR flow rate, the EGR valve opening is regulated manually. Figure 3.7 is valve supplied by GP Valve & Actuator Store Sdn. Bhd is capable of withstanding high pressure and temperature, thus being suitable for this EGR system. The ball valve opening can be reduced thus allowing a higher pressure differential which channels exhaust gas volume according to the percentage of EGR rate desired.the percentage of recycled exhaust gas can be represented by an EGR ratio, which is the mass ratio of recycled gases to the total fresh air intake. The fresh air intake contains negligible amounts of CO2 while the recycled portion carries a substantial amount of CO2 that increases with EGR flow rate and engine loads. Notably, CO2 is merely a combustion product. Thus, it is intuitive and practical, to measure EGR ratio by comparing the CO2 concentrations between the exhaust and intake of the engine as described in equation below:

EGR % = intake CO2 concentration / exhaust CO2 concentration (3.1)

From a general view, the constituent of intake CO2 is affected by the valve opening and the exhaust CO2 concentration. A higher exhaust CO2 concentration leads to a higher intake CO2 concentration and vice versa.

Figure 3: Control valve courtesy of GP Valve & Actuator Store Sdn Bhd

Electrical Power:
Electric power is the rate of doing work, measured in watts, and represented by the letter P:

$$\text{Electrical Power } P(kW) = V \times I \quad (3.2)$$

Where
V = Electric potential or voltage (volts)
I = Electric current in (Amperes)

Exhaust Flow Rate:
From the derivation of Bernoulli's theorem, it is shown that the incoming air velocity at the orifice throat is

$$v = \frac{C_v}{\sqrt{1-\left(\frac{D_2}{D_1}\right)^4}} \sqrt{2\frac{\Delta p}{p}} \quad (3.7)$$

Where,
C_v = Orifice Coefficient
D_2 = Diameter of Orifice (m)
D_1 = Diameter of duct inlet (m)
Δp = Pressure drop across orifice (pa)
p = Density of incoming air (kg/m3)

Specific Fuel Consumption:
The specific fuel consumption (SFC) is the ratio between the mass flow rate of fuel consumed and the unit power output

$$SFC = \frac{m_f}{m_b} \quad (3.8)$$

Where,
m_f = Fuel flow rate
m_b = Unit power output

EGR Percentage and Ratio:
The EGR percentage is a ratio of volume of EGR used divided by the total intake charge into the cylinder:

$$\% \, EGR = \frac{(\rho Av)_{air} - (\rho Av)_{EGR}}{(\rho Av)_{air}} \times 100 \quad (3.14)$$

$$\% \, EGR = \frac{\Delta \dot{m}}{\dot{m}_{air}} \times 100 \quad (3.15)$$

Where
ρ = Density (kg/m^3)
A= Area of pipe flow (m^2)
V= velocity (m/s)

This way can be used to calculate other percentages.

$$EGR\ ratio = \frac{[CO_2]_{intake} - [CO_2]_{ambient}}{[CO_2]_{exhaust} - [CO_2]_{ambient}}$$

3.3 Experiments Method

The experiment will conduct on a single cylinder, four-stroke diesel engine to study the influence of EGR on the engine's performance and emission levels of NO, CO, CO2, and HC. Prior experimentation, the Eddy current dynamometer was allowed to run for 30 minutes meanwhile diesel engine also was allowed to run under the idlecondition for 10 minutes. This step is necessary to warm up the machines and equipment to minimise data editors. The EGR setup consists of a non-insulated stainless steel pipe connected from the exhaust outlet to the air intake duct and a ballvalve installed on this pipe to regulate the volume of exhaust gas recirculation into air intake duct. Non-insulated pipe allows the re-circulated exhaust gas to partially cool down since there is no other EGR cooling mechanism present. An air velocity sensor was used to obtain the readings of the exhaust gas flow rate after fully closingthe valve and again after fully opening the valve. Both readings resemble EGR ratesof 0% and 18.2% respectively and interpolation of both flow rate readings was useful to determine desired EGR rates. EGR rates can be regulated by referring to the air velocity sensor readings display. Data such as power, torque and exhaust gas emission was recorded at EGR rates of 0% (no EGR), 1.09%, 4.35%, 7.6%, 8.2%, 15.7%i, and 18.2% at various engine speeds applied with afull load and partial load.

Power and torque readings were obtained using an Eddy current dynamometer coupled to the engine and at the same time, exhaust gas emission levels wereanalysed using a portable gas analyser. Other important data recorded during theexperiment were temperature readings of intake air and exhaust gas.

Significant effects are likely to occur where valuable resources are subject to impacts of severity. EIA is recognized by adopting the five levels of significance as described in the draft to good practice and procedures. These five levels of significances are:

- Severe: Sites of national importance and unique resources (to exist in only one place) if lost, cannot be replaced or relocated.
- Major: These effects are to be important considerations at a regional or district scale during the decision making process.
- Moderate: These effects at a local scale are likely to be key decision making issues.
- Minor: These effects may be raised as local issues but are unimportant in the decision making process.
- Neutral: No effect, not significant.

4. Results and Discussion

Performances of Diesel Engine with EGR use different fuel (diesel & biodiesel) was analysed and compared with the provided benchmark performances of the diesel engine to ensure reliability of data obtained from experiment• Operation: monitoring of effectiveness of built-in safeguards.

4.1 Engine Performance

Engine power

The power output is very important to evaluate the engine. Figure 4.1 is shown below Power diesel engine speed (rpm):at the speed of 2600 rpm (advised max speed) the maximum power will be achieved accordingly to different EGR ratio 30% valve opening is the best value for the experiment it showed that the more EGR ratio the best power will perform it is suggested for the best power with less EGR additional will enhance the performance of the engine power for the experiment it showed that the more EGR ratio being reduced the best power will perform it is suggested for the best power, fuel consumption with less EGR additional will enhance the performance of the engine power.

Adding EGR to a diesel reduces the specific heat ratio of the combustion gases in the power stroke. This reduces the amount of power that can be extracted by the piston. EGR also tends to reduce the amount of fuel burned in the power stroke. This is evident by the increase in particulate emissions that corresponds to an increase in EGR when increasing the power was increased until 50% EGR and then the ratio of EGR, began to decrease when the value of EGR become more than 50 This is because the engine is incapable of handling too much of EGR volume that lead engine to knocking and decrease performance Another reason is that EGR reduces the combustion temperature which results in decreasing thermal efficiency that in turn reduces engine power.

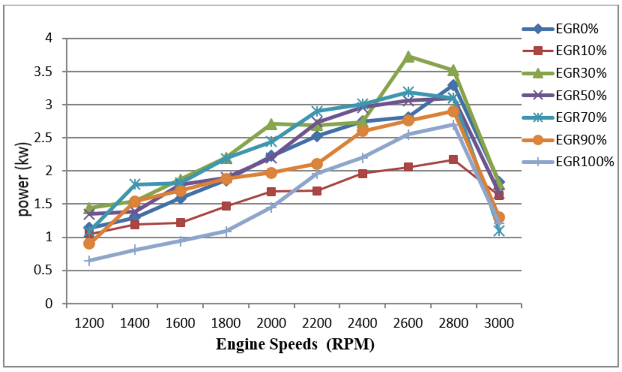

Figure 4.1: Power (KW) vs engine speed (RPM) under different EGR ratio with fuel diesel.

Figure 4.2 is shown below Power dieselengine speed (rpm) with biodiesel at the speed of 2600 rpm (advised max speed) the maximum power will be achieved accordingly to different EGR ratio 30% valve opening is the best value for the experiment. This is evident by the increase in particulate emissions that corresponds to an increase in EGR when increasing the power was increased until 50% EGR and then the ratio of EGR, began to decrease when the value of EGR become more than 50 This is because the engine is incapable of handling too much of EGR volume that lead engine to knocking and decrease performance Another reason is that EGR reduces the combustion temperature which results in decreasing thermal efficiency that in turn reduces engine power.

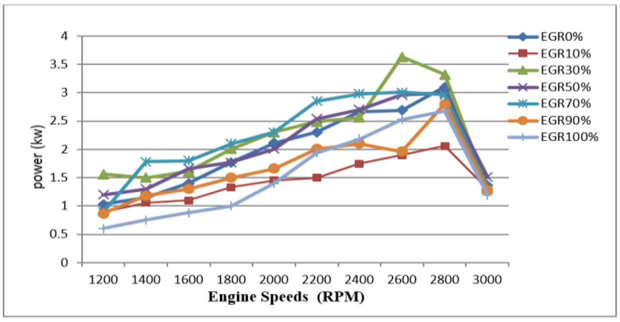

Figure 4. 2: Power (KW) vs engine speed (RPM) under different EGR ratio with fuel biodiesel.

Figure 4.3 is shown below Engine running with palm biodiesel has lower powercompared to conventional diesel. Lower heating value and higher density as well as the higher viscosity of palm-biodiesel were found to be the major factors for the results. EGR employment on diesel engine for the fuel tests also establishes profound results. Conventional diesel with EGR has produced lower power compared to the condition without EGR due to different combustion efficiency of the engine. This result shows that when diesel engine operating with EGR, engine power dropped rapidly due to lower oxygen burned in the chamber and leads to incomplete fuel burning as well as lower thermal efficiency.

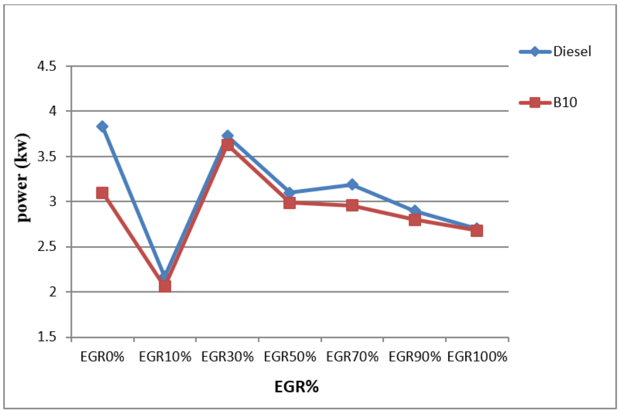

Figure 4.3: Power (kW) versus EGR rate percentage of biodiesel-diesel.

4.2 Engine Torque

Engine torque was measured by Eddy Current Dynamometer which was established in engine Lab. As shown in Figure 4.2. 10% opening is the best for torque reliability and stability at vary speeds from 1200 rpm to 3000 rpm. At first the torque was increased and then beyond 7.6 t was decreased. This is due to the loss in thema efficiency as explained earlier

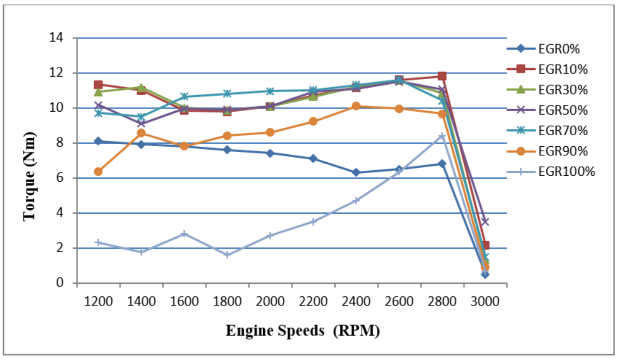

Figure 4.4: Torque (Nm) vs engine speed (RPM) under different EGR ratio with fuel diesel.

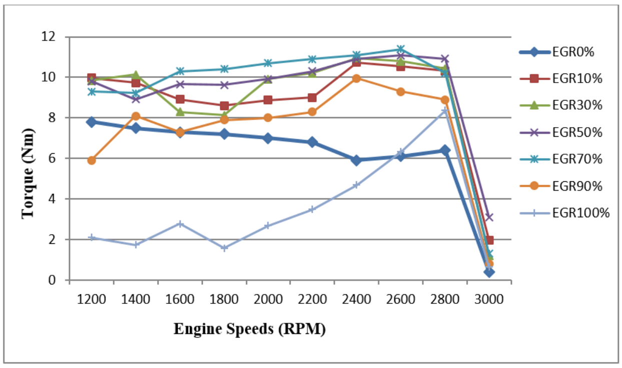

Figure 4.5: Torque (Nm) vs engine speed (RPM) under different EGR ratio with fuel biodiesel.

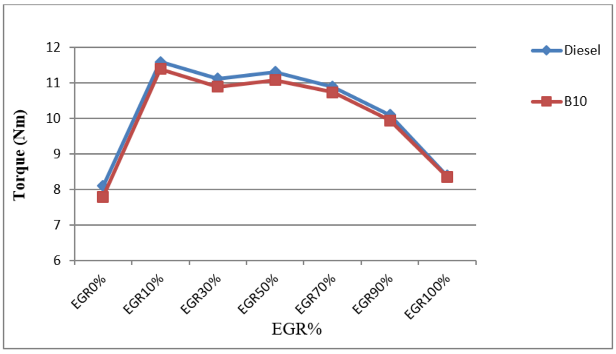

Figure 4.6: Torque (Nm) versus EGR rate percentage of biodiesel-diesel.

4.3 Emissions Levels

Carbon Monoxide (CO)

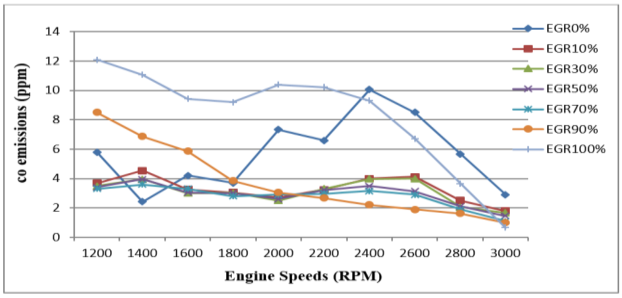

Figure 4.7: CO (ppm) vs engine speed (RPM) under different EGR ratio with fuel diesel.

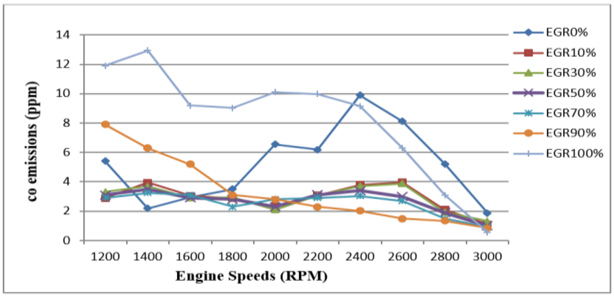

Figure 4.8: CO (ppm) vs engine speed (RPM) under different EGR ratio with fuel biodiesel.

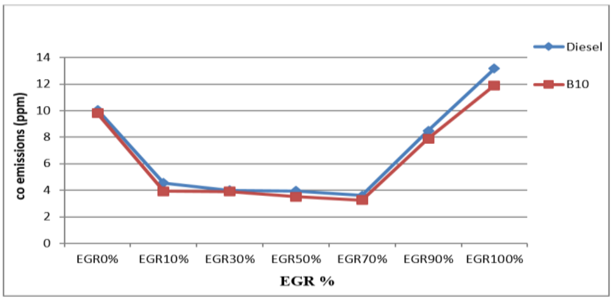

Figure 4.9: CO (ppm) versus EGR rate percentage of biodiesel-diesel

4.4 Carbon Dioxide (CO2)

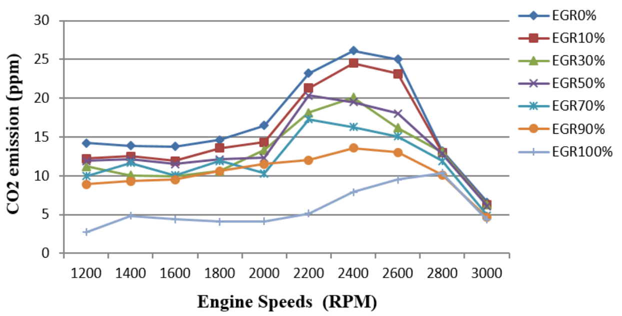

Figure 4.10: CO2 (ppm) vs engine speed (RPM) under different EGR ratio with fuel diesel.

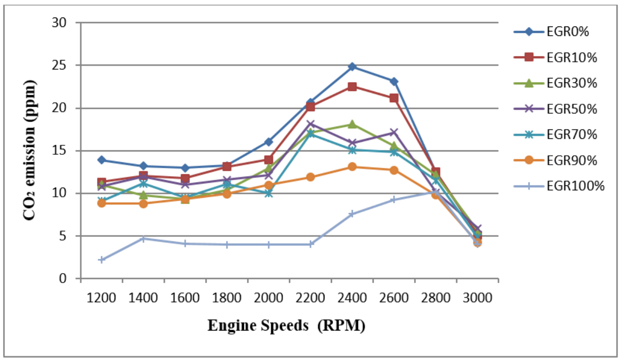

Figure 4.11: CO2 (ppm) vs engine speed (RPM) under different EGR ratio with fuel biodiesel.

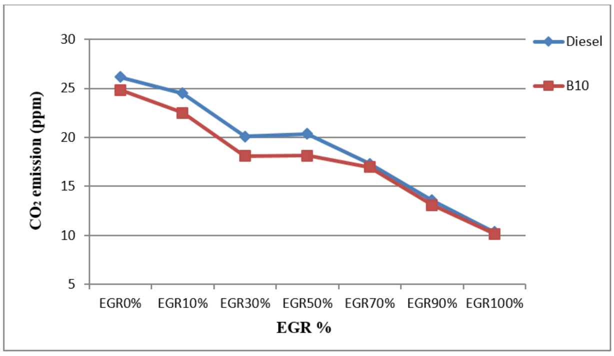

Figure 4.12: CO2 (ppm) versus EGR rate percentage of biodiesel-diesel.

4.5 Nitrogen Oxides NO

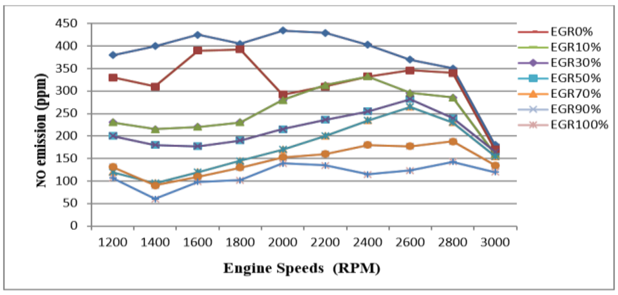

Figure 4.13: NO (ppm) vs engine speed (RPM) under different EGR ratio with fuel diesel.

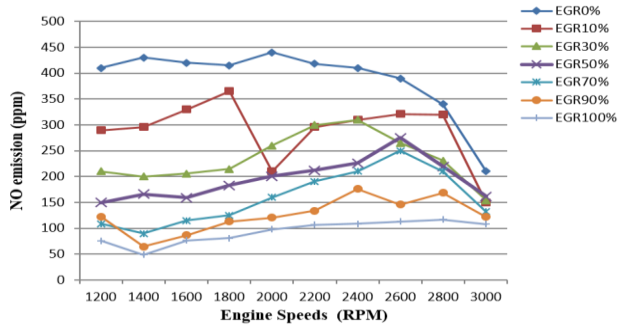

Figure 4.14: NO (ppm) vs engine speed (RPM) under different EGR ratio with fuel biodiesel.

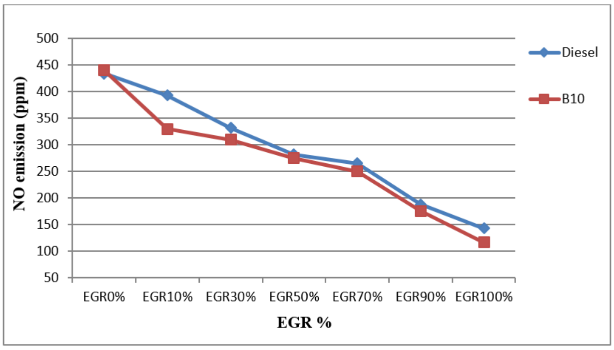

Figure 4.15: NO (ppm) versus EGR rate percentage of biodiesel-diesel.

4.6 Unburned Hydrocarbon (UHC)

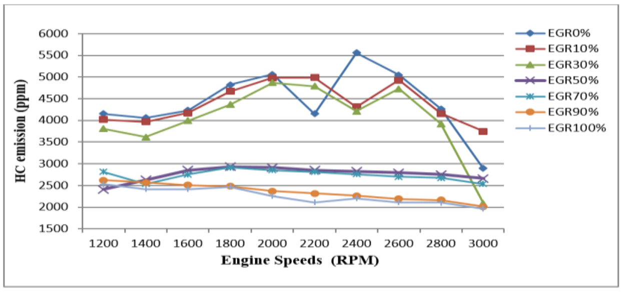

Figure 4.16: HC (ppm) vs engine speed (RPM) under different EGR ratio with fuel diesel

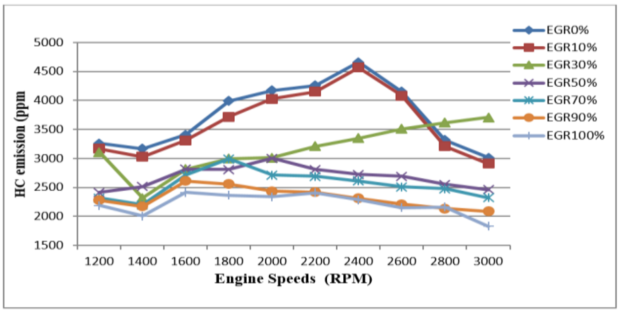

Figure 4.17: HC (ppm) vs engine speed (RPM) under different EGR ratio with fuel biodiesel.

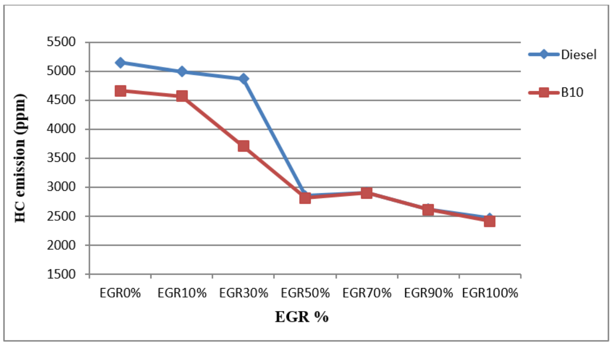

Figure 4.18: HC (ppm) versus EGR rate percentage of biodiesel-diesel.

4.7 Fuel Consumption

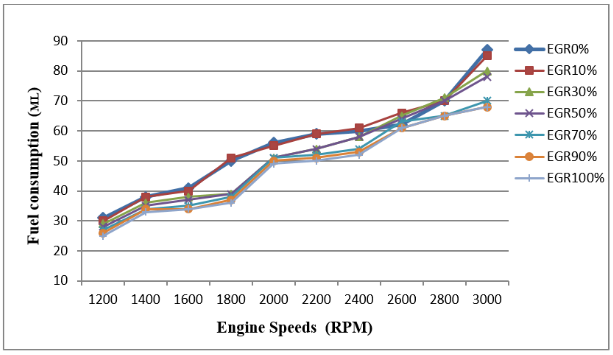

Figure 4.19: Fuel Consuption (ML) vs engine speed (RPM) under different EGR ratio with fuel diesel.

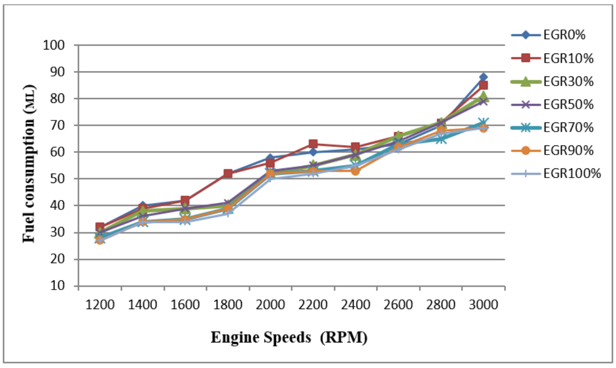

Figure 4.20: Fuel Consumption (ML) vs engine speed (RPM) under different EGR ratio with fuel biodiesel.

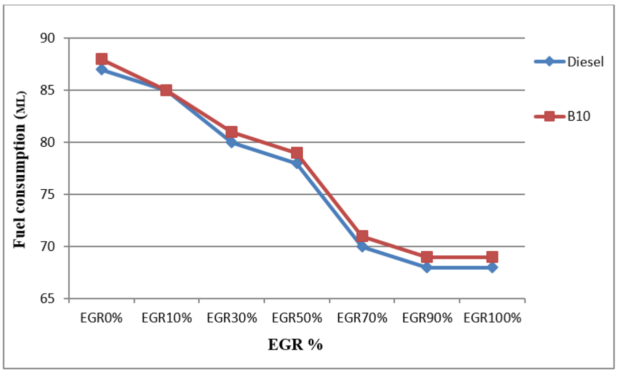

Figure 4.21: Fuel Consumption (ML) versus EGR rate percentage of biodiesel-diesel.

5. Conclusion

Emissions from diesel engines are significant impacting on the environment. In diesel engines, No emissions can be suppressed by reducing peak combustion temperatures and there are two methods to reduce peak combustion temperatures which are either using an injection control system or EGR. Between both mentioned methods. EGR is found to be a better way to control NO,Exhaust gas recirculation reduces the formation of(NO) by allowing a small amount of exhaust gas to recirculate into the intake manifold.A comparative study of biodiesel and diesel. This study was done experimentally in Yanmar diesel engine which has single cylinder and using direct injection method. The outcome of theinvestigation can be summarized as follows:

- Biodiesel has increased the specific fuel consumption (SFC) and reduced the engine performance of the diesel engine include engine power and torque compared to net diesel fuel.
- It is observed that the NO emissions increase directly with increasing biodiesel percentage. Using EGR was an effective technique to reduce the NO emissions. The NO emissions were decreased with increase in EGR flow percentage for both net diesel fuel.
- Biodiesel has higher oxygen-natured, which leads to better combustion, produced higher NO emission in exchange.
- This higher NO emission can be effectively controlled by using EGR.
- EGR increases the CO and HC emissions due to incomplete combustion and reduced the exhaust temperature in advance.
- In summary, engine operation fueled with diesel and palm-biodiesel while employing EGR results in NOx emission reductions without neglecting engine performance as well as exhaust emissions.

6. Recommendations

The purpose of this project is to observe the effect of EGR on diesel engine's performances and emissions level. There are more improvisation and additions that can be done to give better understanding of EGR functions in enhancing diesel engine's performances and reducing emissions level.

- Implementing Cooled EGR can be considered as it might produces lower thermal efficiency and possibly lower NoXemissions.
- Other NOx reducing method or technology such as Variable Compression Ratio (VCR) to be included in future studies as this approach may produce better engine efficiency and also at the same time lower NOx emission.
- In the future, EGR system should be upgraded to optimise the using of exhaust gases EGR valve opening automatically to allow certain parameters to be controlled. Let say once in cool start valve will close 100% and for steady temperature valve opening 10%.

References

[1] Abdullah, A. Z., Salamatinia, B., Mootabadi, H., & Bhatia, S. (2009). Current status and policies on biodiesel industry in Malaysia as the world's leading producer of palm oil . Energy Policy , 37(12), 5440-5448.

[2] Abu-Jrai, A., Rodríguez-Fernández, J., Tsolakis, A., Megaritis, A., Theinnoi, K., Cracknell, R. F., & Clark, R. H. (2009). Performance, combustion and emissions of a diesel engine operated with reformed EGR . Comparison of diesel and GTL fuelling . Fuel, 88(6), 1031-1041.

[3] Alegret, G., Llamas, X., Vejlgaard-Laursen, M., & Eriksson, L. (2015). Modeling of a Large Marine Two-Stroke Diesel Engine with Cylinder Bypass Valve and EGR System. IFAC-PapersOnLine, 48(16), 273-278. [4] Gnansounou, E., &

[4] Cohn, D. R., Bromberg, L., & Heywood, J. B. (2005). Direct Injection Ethanol Boosted Gasoline Engines: Biofuel Leveraging for Cost Effective Reduction of Oil Dependencies and CO2 Emissions. Plasma Science and Fusion Center, Massachusetts Institute of Technology.

[5] Crane Co, CRANE ChemPhanna Energy. (2015).Krombach® throttle valves type 220,http://Www.cranecpe.com/chemenergv/products/valves/throttle-valves/krombach-throttle-valves-type-220 (08 June 2015).

[6] Czarnowski, R., Joergl, V., Weber, O., Shutty, J., & Keller, P. (2008, August). Can Future Emissions Limits be Met with a Hybrid EGR System Alone ?. In US Dept. of Energy Diesel Engine Emissions and Energy Reductions Conference (DEER), Detroit.

[7] Deepan, G. (2013, April). Experimental investigation of performance and emission characteristics in a variable compression ratio diesel engine using partly cold exhaust gas recirculation (EGR) method. In Energy Efficient Technologies for Sustainability (ICEETS), 2013 International Conference on (pp. 727-739). IEEE.