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# Performance and emission analysis of waste vegetable oil and it's blends with diesel and additive

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**ABSTRACT**
The sources of fossil fuels were depleting day to day and there are no more fossil fuels in the future, so there is a need for the search for the alternate fuels. In the present work, the performance and emissions of diesel and diesel additive blended with waste vegetable oil is studied, where the fuel, namely, methyl ester of waste vegetable oil and diesel with additive were chosen and used as fuel in the form of blends. This work presents the experimental investigation carried on computerized four stroke single cylinder diesel engine with Ethanol and Ethyl Hexyl Nitrate (EHN) as additives to the diesel-biodiesel blends. Ethanol was added as 5% and 10% by volume to the diesel-biodiesel blends and Ethyl Hexyl Nitrate (EHN) was added as 0.5% and 1% to the diesel-biodiesel blends. In the present work the bio diesel is the waste vegetable oil which is obtained from the crude waste vegetable oil by using the transesterification process. The results show a 25% reduction in HC emissions with B20 and 35% reduction with B20+Additive and a 15.8% reduction in CO emissions with B20 and 16.3% reduction with B20+additive for the 20% waste vegetable oil blend and Additive with a 15.4% increase for B20 blend and 1.29% decrease when Additive added to blend in NOx emission at full load. There was a 0.275% decreases in brake thermal efficiency for B20 blend and 0.175% increase with Additive to blend for B20 at full load**.**

***Keywords*** - Blend, diesel additive, diesel engine, Engine performance & emission, waste vegetable oil, diesel,

## I. INTRODUCTION

Bio-diesel is not your regular vegetable oil and is not safe to swallow. However, biodiesel is considered biodegradable, so it is considered to be much less harmful to the environment if spilled. Biodiesel also has been shown to produce lower tailpipe emissions than regular fuel. The best thing about biodiesel is that it is made from plants and animals, which are renewable resources.

The depletion of world petroleum sources and increased environmental concerns has stimulated recent interest in alternative sources for petroleum based fuels. Biodiesel produced from vegetable oil or animal fats by transesterification with alcohol like methanol and ethanol is recommended for use as a substitute for petroleum-based diesel mainly because biodiesel is an oxygenated, renewable, biodegradable and environmentally friendly bio-fuel with similar flow performance and low emission profile. The used cooking oil has been classified as waste, while its potential as a liquid fuel through physical and chemical conversion remains highly interesting. It is increasingly attracting much interest because of its great potential to be used as a diesel substitute known as biodiesel. Direct process via transesterification of cooking oils will give biodiesel. One of the advantages of these fuels is reduced exhaust gas emissions. Experience has shown that vegetable oil based fuels can significantly reduce exhaust gas emissions, including carbon monoxide (CO), carbon dioxide (CO2), and particulate matter (PM). Because of their less concentration of sulfur, the sulfur dioxide greases cannot only reduce the burden of the government in disposing the waste, maintaining public sewers and treating the oily wastewater, but also helps in lowering the production cost of biodiesel significantly. Furthermore, biodiesel fuel has been shown to be successfully produced from waste cooking oils by an alkali-catalyzed transesterification process and can be considered as alternative fuel in diesel engines and other utilities.There is need to convert waste cooking oil from kitchen waste into biodiesel and transesterification is the most suitable process for this conversion. The present investigation used the performance and emissions of diesel and diesel additive blended with waste vegetable oil is studied and the best performances of oil blends were identified. The blended form of waste vegetable oil and diesel does not require any engine modification. Hence, this investigation mainly focused on the performance and emissions of diesel and diesel additive blended with waste vegetable oil in the proportionate ratios.

In this work, the waste vegetable oil is vegetable oil mixed with diesel at different blends and these blends are further tested by adding diesel additive. The performance and emissions of bio fuel blends were evaluated using a naturally aspirated computerised single cylinder water cooled direct injection diesel engine and these are plotted on graphs. Ever increasing fuel price, continuous addition of on road vehicles, fast depleting petroleum resources and continuing accumulation greenhouse gases are the main reasons for the development of alternative fuels.

## II. MATERIALS AND METHODS

1.1 Preparation of Waste vegetable Oil Methyl Ester (WVME)

Used sunflower oil collected from the restaurants is considered as feedstock for the biodiesel production. Transesterification is a chemical process of transforming large, branched, triglyceride molecules of vegetable oils and fats into smaller, straight chain molecules, almost similar in size to the molecules of the species present in diesel fuel. The process takes place by reacting the vegetable oil with an alcohol in the presence of catalyst. Methyl esters are preferred as methanol is non hygroscopic and is less expensive than other alcohols. In general, due to high value of free fatty acids (FFA) of waste vegetable oils, acid catalysed transesterification is adopted [29],[30]. However, FFA of the feedstock used in this work is less and hence alkali catalyzed transesterification process [31]-[33] is employed for the conversion of waste vegetable oil into ester. The waste vegetable oil is preheated in a reactor to remove the moisture. Potassium methoxide is prepared by dissolving potassium hydroxide in methanol. Various concentration of KOH in the methoxide was prepared and the process is optimized for the maximum yield. For the optimized KOH concentration, alcohol proportion also optimized to obtain the maximum yield. Methoxide is mixed with preheated oil and the reaction carried out under nominal speed stirring by a mechanized stirrer and at a constant reaction temperature of 55°C for 2 hours. After 3 hours of settling period, ester separates as an upper layer and glycerol settles at bottom separated by decantation. These esters is washed with warm water to remove impurities and separated. Experimentally the process parameters are optimized. The optimum proportions are for one litre of waste vegetable oil, the requirement of methanol and KOH are 200 ml and 7.75g respectively. With this proportion from one litre of used cooking oil, 920 ml of WVME was produced.

1.2 Properties of waste vegetable oil

The properties of methyl ester of waste vegetable oil are compared with diesel and given in table1.It is observed that both the oils have important properties comparable with each other. The properties of waste vegetable oil like lower calorific value, flash point and viscosity are comparable with diesel oil.

Table1.Properties of diesel, waste vegetable oil

| Properties | Diesel | Waste vegetable oil |
|---|---|---|
| Density @ 15$^{o}$C in gm/cc | 0.845 | 0.8868 |
| Viscosity @ 40$^{o}$C | 3.25 | 6.05 cst |
| Flash Point by PMCC method | 32 | 52$^{o}$C |
| Fire Point by PMCC method | 78 | 86$^{o}$C |
| Gross Calorific Value in Kcal/kg | 10800 | 8919 |

1.3 Expermental set up

The performance tests were carried on a single cylinder, four strokes naturally aspirated, and water-cooled kirloskar computerized diesel engine test rig. Diesel engine was directly coupled to an eddy current dynamometer. The engine and dynamometer were interfaced to a control panel, which was connected to a computer. This computerized test rig was used for recording the test parameters such as fuel flow rate, temperature, air flow rate, and load for calculating the engine performance such as mean effective pressure, power, brake specific fuel consumption, brake thermal efficiency, and emission like HC, CO, NOx and smoke. The exhaust gas temperature, inlet and outlet water temperatures were measured through the data acquisition system and were fed to the computer. The exhaust gas was made to pass through the probe of Crypton computerized exhaust gas analyzer for the measurement of HC, CO, NOx and later passed through the probe of smoke meter of Bosch type for the measurement of smoke opacity. A whole set of experiments were conducted at the engine speed of 1500 rpm and compression ratio of 17.5:1.. After setting the engine speed and load to required values the following observations and subsequent calculations were made

1) Exhaust gas temperature
2) Inlet and outlet water temperature.
3) Air flow rate.

4) HC, CO, NOx and smoke are recorded for various loads and injection timing at this Condition.

5) Power, Thermal efficiency, Specific fuel consumption, Pressure with various crank angles.

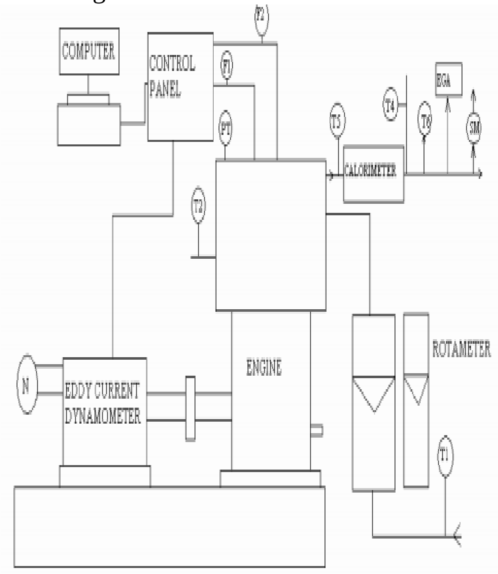


Fig.1. Experimental set up

T1, T3- Inlet water temperature
T2- Outlet engine jacket water temperature
T4- Outlet calorimeter water temperature
T5- Exhaust gas temperature before calorimeter
T6- Exhaust gas temperature after calorimeter
N- Rpm decoder
F1- Fuel flow difference pressure unit
F2- Air intake difference pressure unit
PT- Pressure transducer
EGA- Exhaust gas analyzer (Five gases)

## III. PERFORMANCE ANALYSIS

1.1 Brake Thermal Efficiency

Fig.2 shows that brake thermal efficiency of waste coocking oil and its blends is lower compared to that of diesel.From the graph comparatively higher brake thermal efficiency for B20 blend and with additive. When they are added the viscosity is reduced and moderate calorific value. This may be the reasons for better performance of B20 blend and with additive than that of standard Diesel operation. The reduction in viscosity leads to improved atomization, fuel vaporization and combustion. It may be also due to better utilization of heat energy and better air entrainment. The mixing of additive oil in the blend causes longer ignition delay and rapid combustion. During longer ignition delay engine accumulate more fuel before commencement of combustion and release more heat during premixed phase of combustion. The brake thermal efficiency of B20 blend is 37.855% and it is 0.275% less than that of standard diesel operation. On the other hand, the mixing of diesel additive to B20 blend it has the efficiency of 38.305% and it is 0.175% higher than that of efficiency obtained from B20(WVO20%+diesel80%).

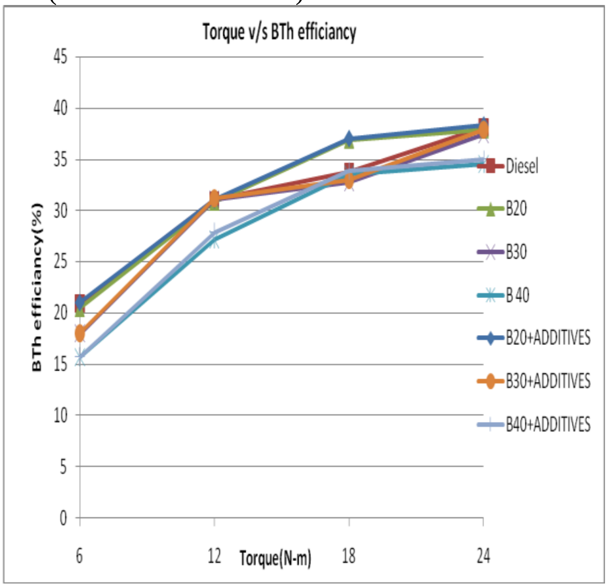


Fig.2.Torque v/s BTh efficiency

1.2 Brake Specific Fuel Consumption

Fig.3 shows brake specific fuel consumption of engine against load. The plot it is reveals that as the load increases the fuel consumption decreases.The specific fuel consumption is higher in biodiesel ; as compared to diesel .The reason is that fuel has lower calorific value. As a result to produce the same amount of energy,more amount of biodiesel consumed.As the percentage of biodiesel in blend increases the break specific fuel consumptions increases. From figure 3 it is seen that at low load the BSFC is 0.373 KG/KW hr for diesel and for B20 blend is 0.382KG/KWhr. At full load the BSFC is 0.205 KG/KW hr for diesel and for B20 blend is 0.21 KG/KW hr. The brake specific fuel consumption of the B20 blend and the BSFC after mixing Additive was lower than that of all other. This may be due to better combustion and an increase in the energy content of the blend. Additive mixed blend and diesel have low BSFC.

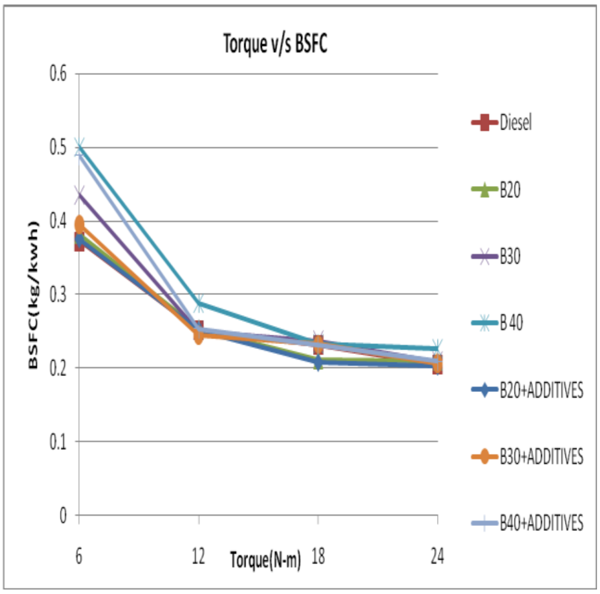


Fig.3.Torque v/s BSFC

## IV. EMISSION ANALYSIS

1.1 Carbon Monoxide (CO) Emission

The figure 4 shows the CO emission of blends with various loads.The plot it is observed that is interesting to note that the engine emits more CO for diesel as compared to biodiesel blends under all loading conditions. The CO emission of B20 blends decreased significantly at full load. This may be due to the enrichment of oxygen in the waste vegetable oil, in which an increase in the proportion of oxygen promotes further oxidation of CO during the engine exhaust process. At lower waste vegetable oil concentration, the oxygen present in the biodiesel aids for complete combustion. However as the waste vegetable oil concentration increases, the negative effect due to viscosity and small increase in specific gravity suppresses the complete combustion process, which produces small amount of CO. There was a 15.8% reduction of CO emission for the B20 blend at sssfull load. The mixing of Additive to B20 blend has 16.3% reduction in CO emissions when compared to diesel. At no load the diesel has very low CO emission and it is goes on increasing as the load is increasing from 6 to 24 N-m. Similarly B20 blend also has low emissions on low load and increasing it by load on an engine. All the blends have low CO emissions at all loads compared to diesel. The value of CO percentage in exhaust gas is nearer to all blends at lower loads and it is much more difference at higher loads.

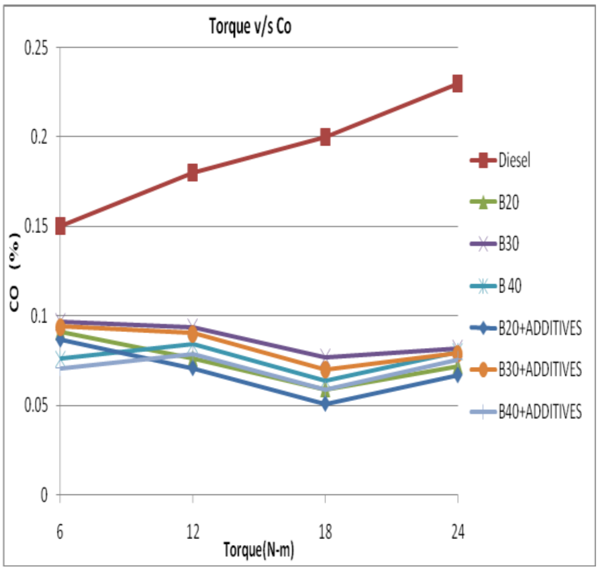


Fig.4.Torque v/s co

1.2 Unburned Hydrocarbon Emission

The Fig. 5 shows that the variation of HC emission of Diesel- waste vegetable oil blends fuel under various engine loads. The plot it is observed that the load increases the HC emission increases for diesel as well as blends. It is seen that HC emissions for diesel fuel is 40 ppm at low load and 62 ppm at full load and for B20 blend it is 17 ppm at low load and 30 ppm at full load. For B20 blends, the HC emissions are lower than that of diesel fuel, and this may be due to complete combustion. There are normally some regions within the combustion chamber of an engine fueled with methyl ester where the mixture is either too rich to ignite the partially decomposed and oxidized fuel in the exhaust. Those un-burnt species are collectively known as un-burnt hydrocarbon emissions. The mixing of Additive to B20 blend has the HC emission 14 ppm at low load and 26 ppm at full load. Always there was reduction in HC emissions in both B20 blends and mixing of additive to fuels. The reduction in HC Emissions is goes on increasing with increase in load from no load to high load. It is better to use 20% waste vegetable oil and 80% diesel blended fuel for reduced emissions of HC. It is observed that the reduction in HC emission at 24 N-m load running on B20 blend was 30ppm, but at low loads the reduction in emissions is less compared to the diesel. The graph clearly shows that there is a decrement in HC emission in diesel and waste vegetable oil blends tested by mixing diesel additive.

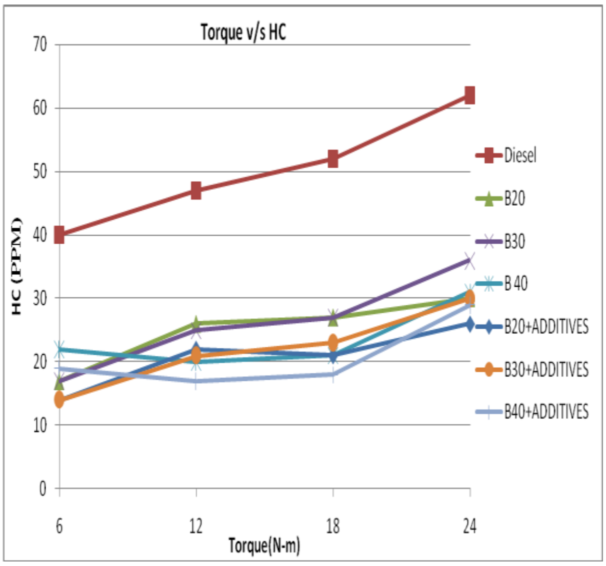


Fig.5.Torque v/s HC

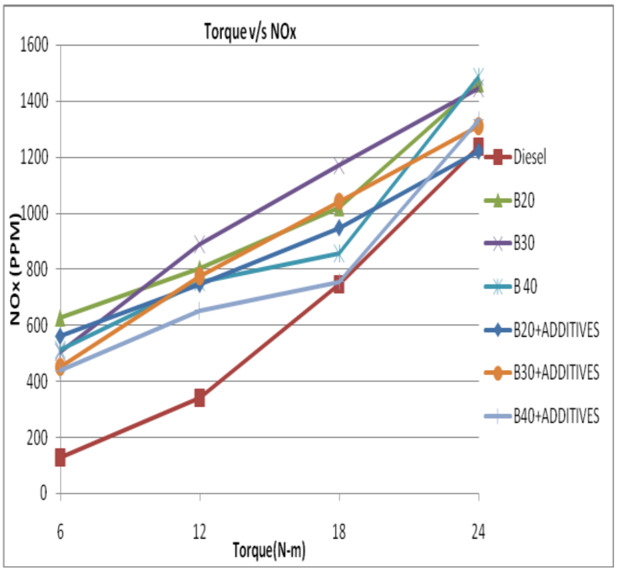


Fig.6.Torque v/s NOx

1.3 Oxides of Nitrogen (NOx) Emissions

Fig. 6 shows that the variation of NOx emission for Diesel-waste vegetable oil blends and standard diesel for different engine loads. The increase in trend may be due to the presence of oxygen in methyl ester of waste vegetable oil, since the oxygen present in the fuel may provide additional oxygen for NOx formation. Many researchers reported that oxygenate fuel blends can cause an increase in NOx emission. Normally complete combustion causes higher combustion temperature which results in higher NOx formation. Another reason for the increase in NOx emission is the cetane suppressing property of oil. Usually, low cetane fuels offer longer ignition delay and release more heat during the premixed phase of combustion. For B20 blend, the NOx emission was 1461 ppm compare to 1236 of Standard diesel. It decreases slightly by adding additive. It is observed that the decrease in NOx is more at maximum loads compared to low and no loads. At B20 blend the NOx emission is 1461 ppm it is higher than the emission recorded when the engine is running on diesel fuel. The mixing of Additive to B20 blend has the NOx emission 560 ppm at low load and 1220 ppm at full load. Always there was reduction in NOx emissions in B2 blend with mixing of additive to fuels. The increase in NOx emission is observed in not only waste vegetable oil but also in all vegetable oils due to the presence of oxygen in the oil extracted from vegetable products. From the figure 8, it is observed that there is no much more increase in NOx emission at lower loads but greater increase may observe when the load on engine is increasing to maximum value. The reduction in NOx emission observed in waste vegetable oil-diesel blends when additive mixed is very low because of additive properties those allows little bit changes in fuel used in engines to reduce NOx emissions.

## V. CONCLUSION

The conclusions derived from present experimental investigations to evaluate performance and emission characteristics on computerized four stroke single cylinder diesel engine fueled with diesel- waste vegetable oil blends with Ethanol and EHN as additives are summarized as follows.

1. Brake thermal efficiency increased with all blends when compared to the conventional diesel fuel. There was a 0.175% increases in brake thermal efficiency with Additive to blend for B20 at full load.
2. The Brake specific fuel consumption is increased with the blends when compared to diesel.
3. CO and HC emissions are decreased significantly with the blends when compared with diesel.
4. Comparatively a slighter increment in NOx emission was found while working with all blend at all loads. And there is a slight decrease by adding additive.
5.From the above analysis the blend B20+Additive shows the better performance and emissions compared to other blend(B20,B30,B40 ,B30+Additive, B40+Additive) and diesel. So the B20+Additive blend can be used as an alternative fuel in DI diesel engine.

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## REFERENCES

[1] Jose M. Desantes, Jean Arregle and Santiago Ruiz and Alain Delage, “Characterisation of the injection-combustion process in a DI

diesel engine running with Rape oil methyl ester" *SAE Technical paper* 1999-01-1497.

[2] D.C. Rakopoulos, C.G. Rakopouls, E.G. Giakoumis, A.M.Dimaratos, M.A. Founti, "Comparative environmental behavior of bus engine operating on blends of diesel fuel with four straight vegetable oils of Greek origin: Sunflower, cottonseed, Corn and olive. *Journal of Fuel* 90 (2011) pp. 3439-3446.

[3] Culshaw F.A., "The potential of biodiesel from oil-seed rape", *Journal of Power and Energy*, Vol. 207, No. A3, pp. 173-181 1993.

[4] Desantes J.M., Arregle J., Pastor J.V., "Influence of the fuel characteristics on the injection process in a DI diesel engine", *SAE Paper* 980802, 1998.

[5] Kaiser W., "The use of alternative fuels in tractor engine – State of development and prospects from a manufacture's viewpoint", Conference "Engine and Environment" *AVL Proceedings*, 1991.

[6] Macchi S., "Overview on Biodiesel Utilisation for S+L+H Tractor engines", conference "*Engine and environment*", AVL Proceedings, 1991.

[7] Payri F., Desantes J.M., Arregle J., "Characterisation of DI diesel sprays in high density conditions", *SAE Paper* 960774, 1996.

[8] Mohamad I. AI-Widyan, M.I., Tashtouch, G. and Abul-Qudais, M.. Utilization of ethyl ester of waste vegetable oils as fuel in diesel engines, *Fuel Processing Technology*, pp. 91-103. 2002.

[9] Rickeart D.J., Thompson N.D., "A review of the potential for bio-fuels as transportation fuels", *SAE paper* 932778, 1993.

[10] Yiannis A. Levendis , Iraklis Pavlatos, Richard F. Abrams, Control of diesel soot, hydrocarbon and NOx emission with particulate trap and EGR. *SAE paper* 940460, 1994.

[11] Ayhan Demirbas, "Biodiesel from waste cooking oil via base-catalytic and supercritical methanol transesterification" *Energy conservation and Management*, Vol.50, Issue 4, pp 923-\927, 2009.

[12] Larsen C, Dey F, Levendis YA, An optimization study on the control of NOx and particulate emissions from diesel engines, *SAE paper* no.960473, 1996.

[13] Komninos NP, Rakopoulos CD. Numerical investigation into the formation of CO and oxygenated and nonoxygenated hydrocarbon emissions from isooctane and ethanol-fueled HCCI engines. *Journal of Energy Fuels* 2010; 24: 1655-67.

[14] Miyamoto N, Ogawa H, Nabi MN. "Approaches to extremely low emissions and efficient diesel combustion with oxygenated fuels. *International Journals of Engine Research* 2000; 1: pp 71-85.

[15] Abu-Jrai A, Rodriguez-Fernandez J, Tsolakis A. Megaritis A. Theinnoi K, Cracknell RF, "Performance, combustion and emissions of a diesel engine operated with reformed EGR, comparison of diesel and GTL fuelling, *Journal of Fuel* 2009, 88 pp. 1031-4.