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Impact of Oxygen Enriched Air Intake on the Exhaust of a Single Cylinder Diesel Engine

Kuppusamy Rajkumar and Palanisamy Govindarajan
Department of Mechanical Engineering, Sona College of Technology, Salem-636005, India

Abstract: Problem statement: The objective of the research is to investigate the effect of using oxygen enriched air on Diesel engine exhaust emission. **Approach:** In the present experimental work a computerized Single cylinder Diesel engine with data acquisition system was used to study the effects of oxygen enriched air intake on Exhaust emissions. Engine test has been carried out in the above said engine for different loads and Exhaust Emissions like CO, CO_2, NOx and HC with respect to different percentage of oxygen enrichment were discussed. **Results and Conclusion:** Increasing the oxygen content with the air leads to faster burn rates and the ability to control Exhaust Emissions. Added oxygen in the combustion air offers more potential for burning diesel. Oxy-fuel combustion reduces the volume of flue gases and reduces the effects of green house effect also.

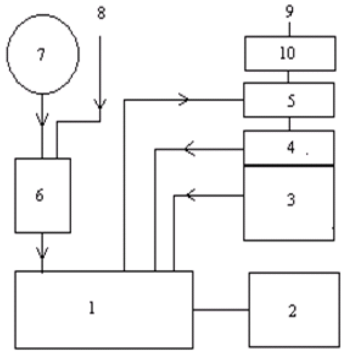
Key words: Oxygen enriched combustion, green house effect, single cylinder, diesel engine, exhaust emissions, acquisition system, fuel consumption, HC emissions, air tank, crank angle

INTRODUCTION

Diesel engine manufacturers face major challenges to meet emissions norms with high combustion efficiency. Moreover how to decrease fuel consumption has put focus on the automobile industry and forced them to produce engines with new Technology. This has led to development of new combustions systems. Lot of research works are going on to meet the above challenges. Today the diesel engine is one of the most exciting and promising technologies in the hunt for new engine solutions for an increasingly eco-aware and resource efficient world. A number of experimental studies have demonstrated the benefits of applying OECT in diesel engines. In the present work separate oxygen cylinder was used to enrich the oxygen level in the intake air. A small mixing chamber was provided before inlet manifold. Use of oxygen enriched air was compared with different load with different level of oxygen enrichment to evaluate the above mentioned parameter. Other aspect of oxygen enrichment like Brake power, Specific fuel consumption, Mean effective pressure, Brake thermal efficiency and Mechanical efficiency are not included in this study.

MATERIALS AND METHODS

The test engine was a single cylinder water cooled kirloskar diesel engine with computerized data acquisition system. The schematic diagram of the experimental setup is shown in Fig. 1. Detailed specifications of the test engine are shown in Table 1.



(1) Engine (2) Eddy current dynamometer (3) Computer with data acquition system (4) Fuel tank (5) Calorimeter (6) Mixing chamber (7) Oxygen cylinder with flow meter (8) Atmospheric air (9) Exhaust gas to the atmosphere (10) Multi gas analyzer

Fig. 1: Experimental setup

Table 1: Engine specification

Make	Kirloskar
BHP	5HP
Speed	1500-2000 rpm
No. Of cylinders	One
Compression ratio	17:1
Bore	70 mm
Stroke	110 mm
Type of Ignition	Compression ignition
Method of loading	Eddy current dynamometer
Method of starting	Manual crank start
Method of cooling	Water

Corresponding Author: Kuppusamy Rajkumar, Department of Mechanical Engineering, Sona College of Technology, Salem-636005, India

Air flow measurement: The air flow to the engine is routed through cubical air tank. The air tank fulfills the purpose of regulating the flow of air to the tank. The inlet of the air tank is provided with an orifice, the air flow rate is measured using the mass air flow sensor. A hot wire mass air flow sensor determines the mass of air flowing in to the engines air intake stream. This is achieved by heating a wire with an electric current that is suspended in the engines air stream. The wire electrical resistance increases with the wires temperature, which limits electrical current flowing through the circuit. When the air flows past the wire, the wire cools decreasing its resistance and reaches equilibrium again. The amount of current required to maintain the wire electrical resistance is directly proportional to the mass of air flowing past the wire. The integrated electronic circuit converts the measurement of current into a voltage signal.

Fuel delivery system: The Fuel from the tank is connected to a solenoid valve. The outlet of the solenoid valve is connected to a glass burette and the same is connected to the engine through a manual ball valve. The fuel solenoid of the tank will remain open until the burette is filled to the high level sensor, during this time the fuel is flowing to the engine directly from fuel tank and also fills the burette. Once after sensing the top level, the fuel solenoid closes fuel tank outlet line, now the fuel in the burette gets discharge to the engine. When the fuel level reaches the high level optical slot sensor, the sequence running in the computer records the time of this event. Likewise when the fuel crosses the low level optical slot sensor, the sequence running in the computer records the time of this event. And immediately the fuel solenoid opens filling up the burette and the cycle is repeated. Here the injection is direct with multi hole nozzle.

Crank angle and method of loading: A 11 bit 2050 step crank angle encoder was mounted on the camshaft to measure engine crank angle. The engine was instrumented with the piezoelectric transducer to measure the combustion process. The pressure transducer is connected to the battery powered signal conditioner via an inline charge amplifier/converter. The charge amplifier converts the low level charge to a high level voltage output, which again conditioned in the signal conditioner and fed to the data acquisition card as a differential connection.

The engine and the air cooled eddy current dynamometer are coupled using a tire coupling, the output shaft of the Eddy current dynamometer is fixed to a strain gauge type load cell for measuring applied load to the engine. The engine is loaded using the potentiometer provided on the panel.

Data acquisition is the sampling of the real world to generate data that can be manipulated by the computer, typically involves acquisition of signals and waveforms and processing the signals to obtain desired information. The components of data acquisition systems include appropriate sensors that convert any instrument parameter to an electrical signal, which is acquired by data acquisition hardware. Acquired data is displaced, analyzed and stored in computer. Data acquisition begins with physical phenomenon or physical property of an object to be measured. This property may be the temperature or temperature change of a room, the intensity or intensity change of a light source, the pressure inside a chamber, the force applied to an object or many other things. An effective data acquisition system can measure all of these different properties or phenomena.

For intake air low levels of oxygen enrichment were used, it did not exceed 4 LPM of the intake air in order to protect the engine. Higher oxygen enrichment levels need special engine modifications because of the expected higher output temperature which is expected to be produced. The intake air oxygen concentration was increased by injecting pure oxygen from a cylinder to the mixing chamber. To ensure effective oxygen enrichment, the pure oxygen was injected directly through mixing chamber in its inlet and the intake air oxygen concentration was measured properly using gas flow meter.

Oxygen supply system: For the purpose of tests reported here compressed oxygen stored in the cylinder was used. The oxygen and the atmospheric air was mixed in the mixing chamber provided before entering to the intake manifold of the engine. A separate oxygen sensor located in the engine intake manifold was used to measure the intake oxygen content of the system. The amount of oxygen supplied from the cylinder varies from 1 Liters Per Minute (LPM) to 4 L min^{-1}.

Combustion Vs O_2 Combustion: Combustion in diesel engines is more complex and its detailed mechanisms are not well understood. Its complexity seems to challenge researchers attempts to release its many secrets despite the availability of modern tools such as high speed photography used in “transparent” engines, computational power of contemporary computers and the many mathematical models designed to take off combustion in diesel engines. The addition of oxygenated fuel can result in a sizable decrease of particulate matter in the exhaust gases (Momani *et al*., 2009).

Oxygen enhanced combustion has become one of the most attracting combustion technologies in the last decades, two developments have increased the significance of it, the first one is new technology of producing oxygen less expensively and the second one is the increased importance of environmental regulations. Oxygen enriched combustion is a proved method to increase available heat value or to reduce fuel consumption. If more oxygen is fed in to the combustion chamber in any engine, then more combustion will be happened and bad emission become less because they will be oxidized (Momani, 2009) In the oxygen enriched combustion the fuel/air mixture ignites and burns in a faster rate resulting in high energy release rates (Rajkumar and Govindarajan, 2010).

RESULTS AND DISCUSSION

Carbon monoxide: CO is generally produced due to in complete combustion of a carbon containing fuel. Generally a combustion system operated with high excess air leads to complete combustion and to minimize CO emissions compared with conventional system, due to more complete combustion. When using high levels of oxygen enrichment causes thermal dissociation, where CO is converted to CO_2 at high temperatures. Effect of Ethanol Addition in the Combustion Process leads to a decrease of power and exhaust gas emissions due to oxygen presence in the fuel (Cahyono and Bakar, 2011). With Oxygen enriched combustion, the engine-out hydrocarbon, CO and smoke emissions throughout the whole start-up process were all reduced considerably (Xiao *et al*., 2007). Experimental studies of oxygen enriched combustion leads to drastic decrease of soot emission as well as reduction of CO and HC without affecting BSFC (Rakopoulos *et al*., 2004). The benefit of the OEA has shown to decrease emissions of carbon monoxide (CO).

From the Table 2 it was very clear that role of oxygen enrichment plays an important role in decreasing CO emissions. From the Fig. 2 one can observe that oxygen enriched combustion produces good results with lower levels of oxygen enrichment. An average decrease of 25-45% decrease in CO emission was observed with the enrichment level of 1 LPM. A maximum of 61% reduction and 66% reduction in CO was obtained for the enrichment level of 2LPM and 3LPM respectively. It has been concluded that OEC plays a greater role in decreasing the CO emission for lower levels of oxygen enrichment with average load.

CO_2: The CO_2 emissions increased with load for all the fuel modes. Higher percentage of CO_2 in the exhaust indicated higher oxidation of fuel at the constant engine speed and release of more heat for power conversion. It also indicated better combustion as more fuel was converted from CO-CO_2.

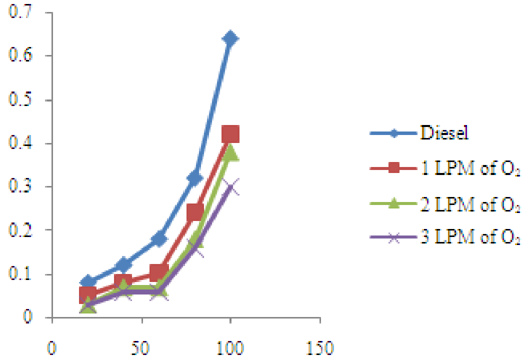


Fig. 2: Variation of CO with % load for varies levels of oxygen enrichment

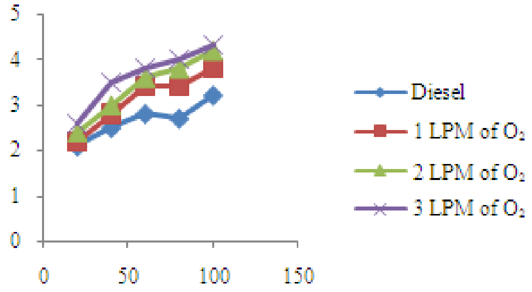


Fig. 3: Variation of CO_2 with % load for varies levels of oxygen enrichment

Table 2: Load Vs CO for varies levels of oxygen enrichment

Load %	Diesel	1 LPM of O_2	2 LPM of O_2	3 LPM of O_2
20	0.08	0.05	0.03	0.03
40	0.12	0.08	0.07	0.06
60	0.18	0.1	0.07	0.06
80	0.32	0.24	0.18	0.16
100	0.64	0.42	0.38	0.3

Table 3: Load Vs CO $_2$ for varies levels of oxygen enrichment

Load (%)	Diesel	1 LPM of O_2	2 LPM of O_2	3 LPM of O_2
20	2.1	2.2	2.4	2.6
40	2.5	2.8	3.0	3.5
60	2.8	3.4	3.6	3.8
80	2.7	3.4	3.8	4.0
100	3.2	3.8	4.2	4.3

With reference to the Table 3 and Fig. 3 CO_2 emissions increased with respect to load for all levels of oxygen enrichment. This is due to more oxygen concentration in the intake air. With high levels of oxygen enrichment CO converted in to CO_2.

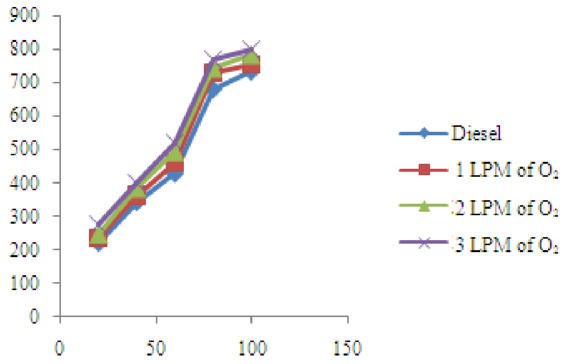


Fig. 4: Variation of NOx with % load for varies levels of oxygen enrichment

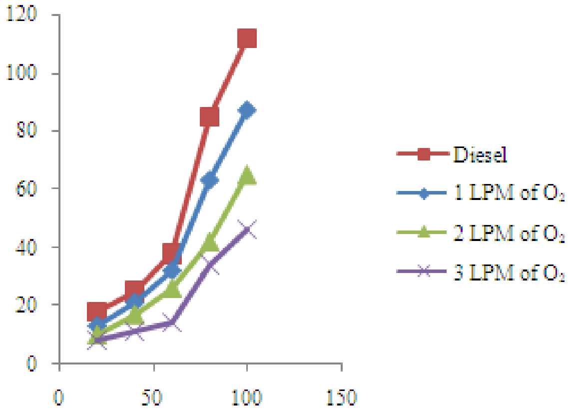


Fig. 5: Variation of HC with % load for varies levels of oxygen enrichment

Table 4: Load Vs NOx for varies levels of oxygen enrichment

Load (%)	Diesel	1 LPM of O_2	2 LPM of O_2	3 LPM of O_2
20	220	235	246	278
40	342	362	384	402
60	428	460	492	520
80	680	730	742	780
100	734	754	782	804

Table 5: Load Vs HC for varies levels of oxygen enrichment

Load (%)	Diesel	1 LPM of O_2	2 LPM of O_2	3 LPM of O_2
20	18	13	10	8
40	25	21	17	11
60	38	32	26	14
80	85	63	42	34
100	112	87	65	46

An average of 5-21% increase in CO_2 was obtained for the enrichment level of 1LPM. A maximum of 29% increase 33% increase in CO_2 was obtained for enrichment level of 2LPM and 3LPM respectively. When comparing with percentage reduction of CO, the increase in CO_2 percentage was less. It was concluded that oxygen enriched combustion increases CO_2 emissions slightly.

But this problem can be managed with exhaust gas recirculation. Moreover increase in CO_2 emissions indicates better combustion since more fuel was converted from CO-CO_2.

NOx emissions: There are three accepted mechanism for NOx production (i) Thermal NOx is produced by the high temperature reaction of nitrogen with oxygen.(N_2+O_2= NO, NO_2). Prompt NOx is formed by the relatively fast reaction between nitrogen, oxygen and hydrocarbon radicals (CH4+ O2+N_2= NO,NO_2,CO_2,H_2O). Prompt NOx is generally an important Mechanism at lower-temperature processes. Fuel Nox is formed by the direct oxidation of organo-nitrogen compounds contained in the fuel (RxN+O_2=NO, NO_2, CO_2, H_2O).

Higher post-flame temperature and oxygen concentrations during the combustion process result in high No formation rates (Heywood, 1988).Oxygen enriched combustion yields higher Nox (Xiao *et al*., 2007; Assanis *et al*., 2001).Emissions of NOx increases exponentially with increasing oxygen concentration.

Form the Table 4 and Fig. 4 it was very clear that NOx emissions increases with load for all levels of oxygen enrichment. An average of 7% increase in NOx was observed for the enrichment level of 1LPM. Similarly a maximum of 14 and 18% increase was obtained for the enrichment levels of 2 LPM and 3 LPM respectively. As a conclusion oxygen enrichment in diesel engine increases NOx emissions, but this problems can be solved by Exhaust gas recirculation and lower levels of oxygen enrichment Injection timings can be retarded to reduce NOx emissions with out increasing the specific fuel consumption.

HC emissions: By applying OECT Hydrocarbon emissions were reduced substantially. Oxygen content in the fuel is main reason for better combustion and HC emissions (Najafi *et al*., 2007).

From Fig. 5 the results HC emissions were reduced significantly at medium load and lower levels of oxygen enrichment considerably at full load of the engine for higher levels of oxygen enrichment. From the Table 5 a maximum of 50 and 65% reduction in the

HC was observed for the enrichment level of 2LPM and 3LPM respectively. An average of 23% reduction in HC was obtained for the enrichment level of 1LPM.

CONCLUSION

Based on the experimental results the following conclusions are drawn.

Oxygen enriched combustion causes significant reduction in CO emissions.

Oxygen enriched combustion technology leads to slight increase in CO_2 and NOx but this problem can be solved with Exhaust gas recirculation.

Oxygen enriched combustion reduces HC emissions considerably.

As a conclusion Oxygen enriched combustion can be consider as a method for reducing exhaust emissions.

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REFERENCES

Assanis, D.N., R.B. Poola, R. Sekar and G.R. Cataldi, 2001. Study of using oxygen-enriched combustion air for locomotive diesel engines. J. Eng. Gas Turbine Power, 123: 157-166. DOI: 10.1115/1.1290590

Cahyono, B. and R.A. Bakar, 2011. Effect of Ethanol Addition in the Combustion Process during Warm-UPS and half open throttle on port-injection gasoline engine. Am. J. Eng. Applied Sci., 4: 66-69. DOI: 10.3844/ajeassp.2011.66.69

Momani, W., 2009. The effects of excess oxygen to mixture on the gasses emissions of a gasoline engine. Am. J. Applied Sci., 6: 1122-1125. DOI: 10.3844/ajassp.2009.1122.1125

Momani, W., S. Abu-Ein, M. Momani and S.M. Fayyad, 2009. Effects of oxygenated gasoline on fuel and air mass flow rates and air-fuel ratio. Am. J. Applied Sci., 6: 974-977. DOI: 10.3844/ajassp.2009.974.977

Najafi, G., B. Ghobadian, T.F. Yusaf and H. Rahimi, 2007. Combustion analysis of a CI engine performance using waste cooking Biodiesel fuel with an artificial neural network aid. Am. J. Applied Sci., 4: 759-767. DOI: 10.3844/ajassp.2007.759.767

Rajkumar, K. and P. Govindarajan, 2010. Experimental investigation of oxygen enriched air intake on combustion parameters of a single cylinder diesel engine. Int. J. Eng. Sci. Technol., 2: 3621-3627.

Rakopoulos, C.D., D.T. Hountalas, T.C. Zannis and Y.A. Levendis, 2004. Operational and environmental evaluation of diesel engines burning oxygen-enriched intake air or oxygen-enriched fuels: A Review. SAE International. DOI: 10.4271/2004-01-2924

Xiao, G.F., X.Q. Qiao, Z. Huang and Z.P. Chen, 2007. Improvement of startability of direct-injection diesel engines by oxygen-enriched intake air. Proceed. Instit. Mech. Eng., Part D: J. Autom. Eng., 221: 1453-1465. DOI: 10.1243/09544070JAUTO541