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Result of Oxygen Enriched Air and EGR on Cylinder Pressure of a Single Cylinder Diesel Engine

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ABSTRACT

The paper describes the result of using oxygen enriched air on maximum pressure of a four stroke single cylinder diesel engine with Exhaust gas recirculation. In general oxygen enriched combustion improves diesel engine performance and reduces carbon monoxide emissions. However, this technique leads to high NOX emissions. But exhaust recirculation technique yields reduction of thermal NOX emitted from a diesel engine. In the present experimental work a computerized single cylinder diesel engine with data acquisition system was sued to study the effects of oxygen enriched air intake on the above mentioned parameters with exhaust gas recirculation. In the present work a maximum enrichment of 3 liter per minute of oxygen was used. Increasing the oxygen content with exhaust gas recirculation leads to higher peak cylinder pressure. But this phenomenon was reversed for more percentage of exhaust gas recirculation

Keywords: *Ignition delay; Oxygen enriched combustion; Cylinder pressure; Exhaust gas recirculation.*

INTRODUCTION

Engine manufacturers face foremost challenges to meet the pollution norms with low exhaust emissions. Moreover how to create nil emission vehicles has put focal point on the automobile industry and put on 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 stimulating and hopeful technologies in the hunt for new engine solutions for an increasingly eco-aware and resource competent world. Remarkable advantages towards the development of cleaner diesel engines have been made over the over the last years, by following various engine-related techniques, such as for example the use of common-rail systems, fuel injection oxygen enriched combustion etc. Diesel engines using oxygen enriched air has many advantages as increased power density, Less smoke, HC and and particulate emissions. Ability to use cheaper, less refined fuels also possible by this technique. But unfortunately oxygen enriched air; yields significant increase in nitric oxides (NOx) emissions [1,2 and 3]. Nitric oxides are mainly formed through thermal mechanism and prompt mechanism [1]. Controlling the thermal NOX emissions requires reduction of combustion temperatures. EGR is one of the most cost-effective techniques currently available for reducing NOX emissions in diesel engines. The use of this technique is increasing rapidly for passenger-car and light truck diesel engines. The effect of EGR on the combustion can be classified into four effects. The first is the dilution effect (reduction in the oxygen concentration of the inlet charge), the second is the thermal effect (higher specific heat capacity of the exhaust as compared with the heat capacity of the atmospheric air), the third effect is the chemical effect (the dissociation of some component of the exhaust) [4], and the fourth Reciprocating engines using oxygen enriched combustion air have several advantages such as increased power density, reduced smoke, hydrocarbon (HC) and particulates emissions, and the ability to use cheaper, less refined fuels.

A number of experimental studies have demonstrated the benefits of applying OECT in diesel engines.[5,6]. 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 with EGR was compared with different load with different level of oxygen enrichment to evaluate the above mentioned parameter. Other aspect of oxygen enrichment like engine performance, reduction in particulates, smoke and unburned HC are not included in this paper.

Experimental Setup

The test engine was a single cylinder water cooled kirloskar diesel engine with computerized data acquisition system. Detailed specifications of the test engine are shown below

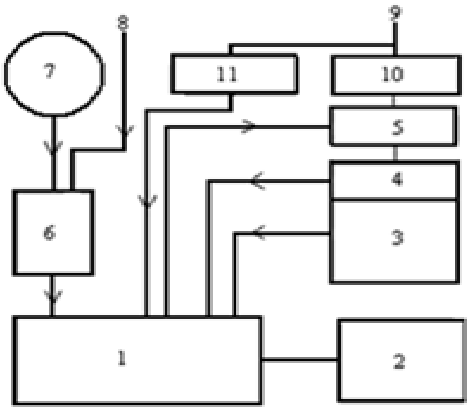

Figure1. *1. Engine 2. Eddy current dynamometer 3. Computer with data acquit ion system 4. Fuel tank 5. Calorimeter 6.Mixing Chamber 8. Atmospheric air 9. Exhaust gas to atmosphere 10. Multigas analyzer 11. Water heat exchanger.*

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 a 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 air flow to the engine is routed through cubical air tank. The air tank fulfils 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.

For intake air low level of oxygen enrichment were used, it did not exceed 4 liters per minute of the intake air in order to product 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.

Table1.

Make	Kirloskar
BHP	5HP
Speed	1500 to 2000 rpm, governed speed of 1500 rpm for CI operation
No. of Cylinders	One
Compression Ratio	17:1
Bore	80 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

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 liters per minute.

Exhaust Gas Recirculation

The engine exhaust gases were passed through a counter flow type water heat exchanger. The heat exchanger can cool down the gases temperature to tap water temperature (i.e. below the surrounding temperature). Down stream the heat exchanger, the gases were divided into two branches. One of them is directed to exhaust pipe while the other to the inlet of engine air port. The latter part of gases was controlled by the use of a gate valve. The amount of EGR can be obtained through the reduction of the inlet air reading which was already determined for each engine speed in case of zero EGR [7]. The exhaust gases temperature can be controlled by controlling the water flow through the heat exchanger by the aid of control valve and water flow meter (Rotameter).

Results and Discussion

Cylinder Pressure

The effect of oxygen enrichment on cylinder pressure shown in the following Graphs. From the graph it was very clear that Oxygen enriched combustion technology influences in increasing the cylinder pressure. This may be attributed to the reduction of the ignition delay period which means early starting of combustion and the availability of longer reaction duration resulting a more completion of the combustion process due to the excess of oxygen and the higher gas temperature. The addition of oxygenated agents results in earlier initiation of combustion and in an increase of maximum combustion pressure, mainly due to the increase of cetane number [6]

Table2. *Variation of Cylinder Pressure with % load for varies levels of O2*

Load	Cylinder Pressure in bar			
	Diesel	O2 1LPM	O2 2LPM	O2 3LPM
20%	52	57	62	68
40%	54	59	63	69
60%	57	62	68	71
80%	60	66	71	75
100%	62	67	72	76

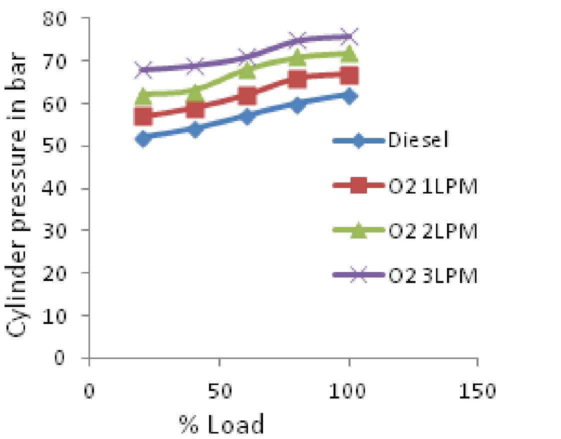

Figure2. *Variation of Cylinder Pressure with % load for varies levels of O2*

A maximum Cylinder pressure of 130 M pa was obtained by previously published data ie by R.R. Sekar et al., 1990 fall technical conference [08]. A four percent increase in cylinder pressure can result in an increase in net engine power of approximately 10 percent stated by Assanis D.N [09].A pressure of 60 bar can be obtained from the test results for the engine with the oxygen level of 1 LPM.

Table3. *Variation of Cylinder Pressure with % load for 1 LPM O2 with varies levels of EGR*

Load	Cylinder Pressure in bar for 1 LPM of O2			
	0 % EGR	15% EGR	30% EGR	45% EGR
20%	57	58	55	52
40%	59	60	57	54
60%	62	62	61	59
80%	66	67	64	62
100%	67	68	63	61

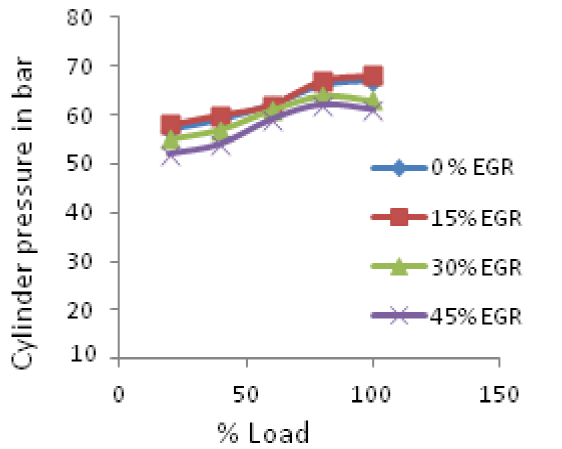

Figure3. *Variation of Cylinder Pressure with % load for 1 LPM O2 with varies levels of EGR*

It is observed that, for 1LPM oxygen enriched air and EGR% up to 15% the change of peak pressure is negligible. The peak pressure is decreased with EGR% above 15%. As mentioned above the pressure of EGR and re- burning UHC tend to increase the peak pressure but the dilution, physical, and thermal effects tend to reduce the peak pressure. So, for EGR% up to 15% the two opposite effects may cancel each other. With higher range of EGR%, the reduction of peak pressure may be due to the reduction of flame temperature that is influenced by the dilution, physical, thermal and chemical effects of EGR. Figure3 shows the effect of oxygen enriched air with and without EGR% on the peak pressure.

Table4. *Variation of Cylinder Pressure with % load for 2 LPM O2 with varies levels of EGR*

Load	Cylinder Pressure in bar for 2LPM of O2			
	0 % EGR	15% EGR	30% EGR	45% EGR
20%	62	63	60	58
40%	63	62	62	60
60%	68	69	65	63
80%	71	72	69	65
100%	72	74	70	67

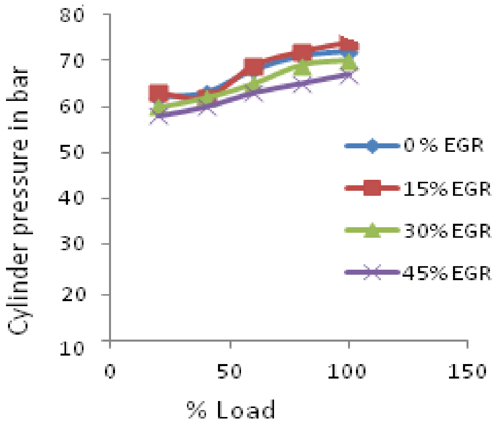

Figure4. *Variation of Cylinder Pressure with % load for 2 LPM O2 with varies levels of EGR*

2LPM of O2 almost follow the same trend as that of 1 LPM of O2 shown in figure 4 and table 4.

In the case of 3LPM oxygen enriched air, a slight increase of the peak pressure is accompanied by increasing the EGR% up to 15% but the peak pressure is decreased with higher EGR%. With EGR% lower than 15%, the pressure of EGR may have the main effect on the peak pressure. The dilution effect can be neglected except with high load where exhaust oxygen percentage is higher than that in naturally aspirated air at low load but the exhaust oxygen percentage is lower than that in natural air at high load. Figure 9 shows the effect of 3LPM oxygen enriched air with and without EGR% on the peak pressure.

Table5. *Variation of Cylinder Pressure with % load for 3 LPM O2 with varies levels of EGR*

Load	**Cylinder Pressure in bar for 3LPM of O2**			
	0 % EGR	**15% EGR**	**30% EGR**	**45% EGR**
20%	62	63	60	58
40%	63	62	62	60
60%	68	69	65	63
80%	71	72	69	65
100%	72	74	70	67

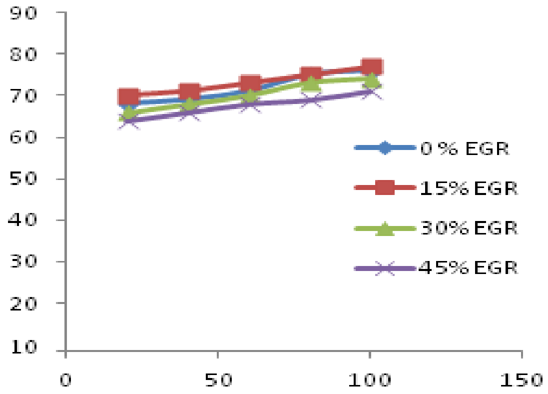

Figure5. *Variation of Cylinder Pressure with % load for 3 LPM O2 with varies levels of EGR*

Conclusions

The use of oxygen enrichment on diesel engine under different loading conditions was studied using computerized engine test rig with data acquisition system to discuss the combustion cylinder pressure. The following observations were made after conducting the experiments, Oxygen enriched combustion influences greater extent in increasing cylinder pressure in the presence of EGR.

12% increase in peak pressure was obtained for the maximum level of oxygen 3 LPM oxygen enrichment. But there is a reasonable increase with 45% of EGR with 2LPM and 3 LPM of O2.

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