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ANALYSIS OF OXYGEN ENRICHED COMBUSTION TECHNOLOGY IN A SINGLE CYLINDER DI DIESEL ENGINE

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Abstract. The effects of Oxygen Enriched Combustion Technology in a single cylinder DI Diesel engine based on performance tests and analysis using Data Acquisition System has been studied in this thesis. This experiment involves the use of zeolite 13X molecular sieves to adsorb nitrogen from air. Pressure Swing Adsorption method is used for controlling the adsorbing and regeneration cycles of Zeolite 13X. It is a compact apparatus which is safe and feasible to fit in CI engine driven automobile. Increasing the oxygen content in the air leads to faster burn rates and increases the combustibility at the same stoichiometry. The Specific power output increases as the thermal efficiency of the engine increases due to the above stated factors. The power produced increases with oxygen enrichment.

Keywords: Oxygen enrichment, Pressure Swing Adsorption, fuel combustibility, performance Characteristics, Zeolite molecular sieve 13X.

I.Introduction

Given the potential to address issues related to limited petroleum reserves and accelerating global climatic change, renewable fuels and improved fuel efficiency are receiving significant research attention. However this experiment is limited to only improving fuel efficiency and performance of the engine. This study concerned with the effects of injecting pure oxygen quantity to the mixture of fuel and air before entering the combustion chamber.

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It is found that the mass flow rate of fuel with the oxygen feeding is less than that of with no oxygen feeding at some specific values of engine speeds and the same thing was found for air mass flow rate. The novelty of this study is to enhance the thermal and mechanical efficiency of the engine and reduce fuel consumption for specific power output values. The stabilization of the engine was tested by repeating the test over 20 cycles and the concurrence of obtained results was checked. Little studies have been discussed this issue, here are some of these studies, Charles and Martin[1] studied in detailed mechanisms by which oxygenated diesel fuels reduce engine-out soot emissions. Their experiments were conducted at a 1200-rpm, moderate-load operating condition using a modern-technology, 4-stroke, heavy duty DI diesel engine with optical access. Images of broadband natural luminosity (i.e., light emission without spectral filtering) from the combustion chamber, coupled with heat-release and efficiency analyses, were presented for three test-fuels. One test fuel (denoted GE80) was oxygenated with tri-propylene glycol methyl ether; the second (denoted BM88) was oxygenated with di-butyl maleate. Differences in the spatial development of ignition or combustion processes among the fuels are evident from the Natural Luminosity (NL) images, Spatially Integrated Natural Luminosity (SINL) data, used as a relative measure of the average in cylinder soot volume fraction, show differences among the fuels. The non-oxygenated CN80 produced 3 times and >7 times higher peak SINL than the oxygenated BM88 and GE80 fuels, respectively. The peak SINL measured for BM88 was twice as great as for GE80, indicating that overall oxygen content is not the only important parameter in determining the soot-reduction potential of an oxygenated fuel.

A.Experimental Setup Block Diagram

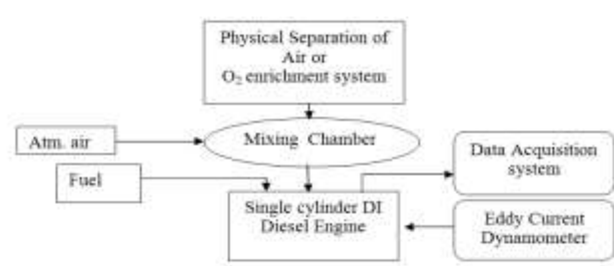

Figure 1

First, atmospheric air is enriched with oxygen by using oxygen enriched system which comprised of pressure swing adsorption system using zeolite molecular sieve 13X. Its flow is then controlled and allowed to mix with atmospheric air in the mixing chamber; this air is then supplied to the air inlet of the diesel engine. Diesel engine is loaded with eddy current dynamometer. Engine is cooled with cold water. Readings are sensed and stored in the computer with data acquisition system software.

B. Data Acquisition System

Data acquisition is the sampling of the real world to generate data that can be manipulated by the computer. It typically involves acquisition of signals and waveforms and processing of the signals to obtain desired information. The components of the 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 the computer.

C. Oxygen Enrichment System

Table 1: Properties of Zeolite molecular Sieve 13X

PARAMETERS	UNIT	TARGET			
Shape		Pellet		Sphere	
Diameter	[mm]	1.5	3.3	4	3
CO2 adsorption	**[NL/g]**	**>15**	**>14**	**>14**	**>15**
N_2 adsorption	%	89	91	93	94

The technique used here is physical separation of air by Pressure Swing Adsorption (PSA) using Zeolite Na12[(AlO2)12.(SiO2)12].27H2O molecular sieve 13X granules. Molecular sieve 13X has a property to adsorb nitrogen at 2 bar pressure and it lets out the adsorbed nitrogen molecules when the Pressure equilibrium is disturbed. This method can be devised in a compact setup and it can be utilized to supply air with enriched oxygen (90-93% purity).

Initially the air is supplied at 2-3 bar pressure using a 2HP air compressor. The moisture in the air is filtered by using a moisture filter which is packed with silica gel. Then it is supplied to a port where it is split into four tubes. We use two cylinders packed with molecular sieve 13X here as it is enough to supply oxygen enriched air to a single cylinder Diesel engine, in case of multiple cylinder engines more number of molecular sieve 13x containers need to be used. The number of containers used will always be in even number.

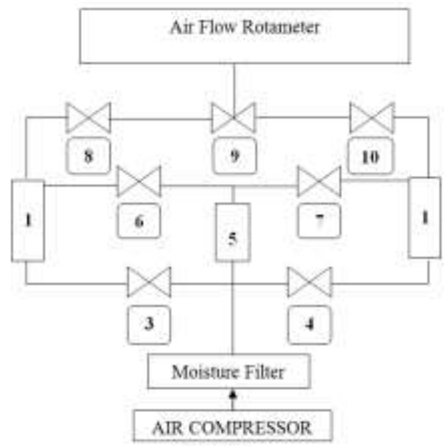

Figure 2

KEY:

1 & 2 – containers packed with molecular sieve 13X

3 & 4 – 3/2 solenoid valves (brass, 230V, 10A AC)

5 – Flow control valve

6, 7, 8 & 10 – 2/2 solenoid valves (230V, 10A AC)

9 – Shuttle valve

Figure 3: photographic view

Then this air is split into three ports, flow through flow control valve (5) is constant and maintained at low rate. The solenoid valves are all in normally closed condition hence only when current is supplied the valve is opened. Hence by using a Program control Logic and relay switched we can control the functioning of all the valves. The valves are timed in such a way that at an instance the valves 4, 10 & 6 are open and others are closed, after 15 minutes the valves

3,8 & 7 are open and others are closed. The flow is directed in such a way that when adsorbent container 1 is functioning the container 2 is regenerating and after duration of 15 minutes the vice versa happens. This process is compact and very easy to fabricate. Practical design of PSA oxygen plants depends on many factors, including bed length, diameter, zeolite bed packing, and rate of air flow. In domestic medical oxygen PSA plants, power efficiency is sacrificed in favor of robustness, process stability and oxygen purity. In larger commercial oxygen plants, the process is only economic whilst operating at maximum oxygen separation efficiency.

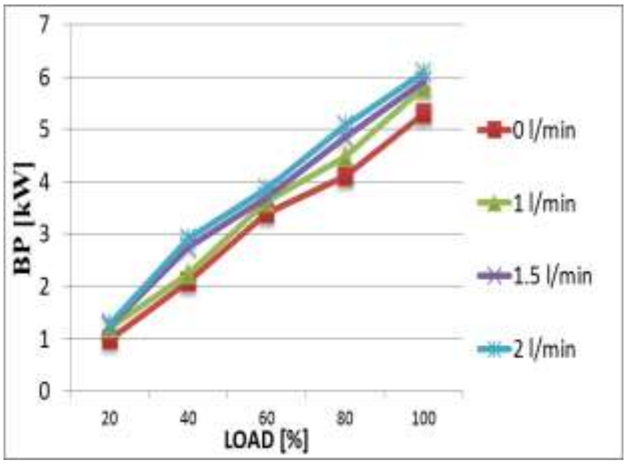

Figure 4: BP [kW] vs Load [%]

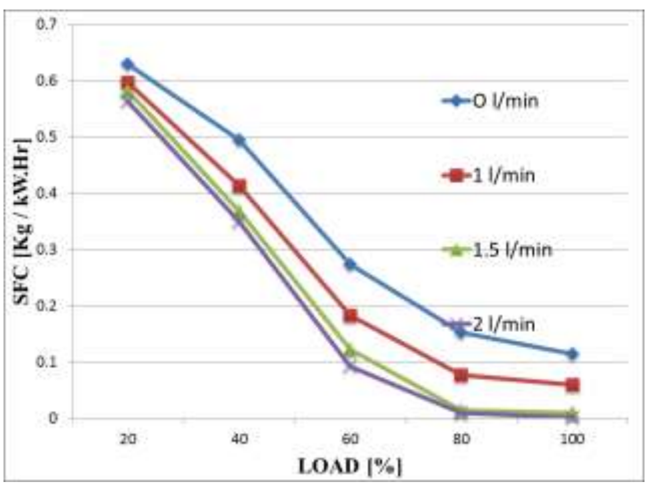

Figure 5: Load [%] vs SFC [Kg/kW.Hr]

Performance Characteristics: The parameters to evaluate the engine performance were BP, specific fuel consumption (SFC), mean effective pressure, mechanical efficiency and exhaust gas temperature. The performance data were collected after stabilization of the engine conditions. Cylinder pressure traces were also collected during the experiments. The experiments were conducted for different loads with different oxygen enrichment levels.

A.Brake Power

One of the objectives of this study was to demonstrate the ability of OECT to increase the power output in a diesel engine, due to the potential to burn more fuel at a given stoichiometry. 40% improvement can be achieved by supplying oxygen at 2 l/min. however more the supply of oxygen causes more possibilities of NOx and Particulate matter (PM).

B.Specific Fuel Consumption

SFC is an important parameter that reflects the performance of the engine [3]. SFC is affected by oxygen enrichment due to the change in the equivalence ratio as oxygen concentration in the intake air changes. Considerable SFC may be achieved from OECT [2]. The fuel consumption in the case of 2 to 3 L/min enriched air is reduced by 5.9%–9.1% as compared with the case of 21% oxygen air at exhaust temperature 773 K [4]. Oxygen enrichment minimized the drop in SFC [5]. Fuel savings are at least 15% compared to the conventional firing [6].Addition of oxygen leads to complete combustion and there by decreases SFC [7].

C. Mean Effective Pressure

A four percent increase in peak cylinder pressure can result in an approximately 10% increase in net engine power when the intake oxygen concentration of 2 L/min is used [2]. Mean effective pressure is a valuable measure of an IC engines capacity to do work that is independent of the engine displacement. Manifold pressure increase is one of the factors that improve the mean effective pressure [3].

D.Mechanical Efficiency

Oxygen enriched combustion also plays a role in increasing mechanical efficiency [1]. Since η m is the ratio of output divided by input, when the power output of the system increases automatically, mechanical efficiency also increases. A set of mechanical efficiency were computed with different load for varies levels of oxygen enrichment.

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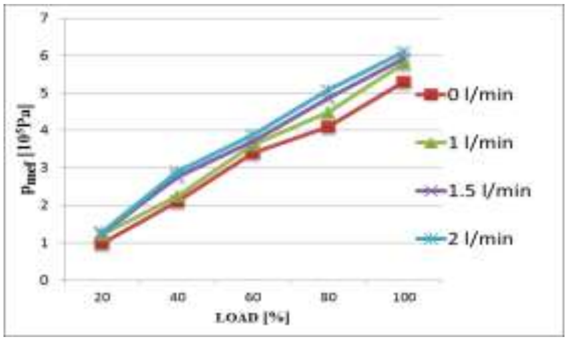

Figure 6: Load[%] vs Pmef [105Pa]

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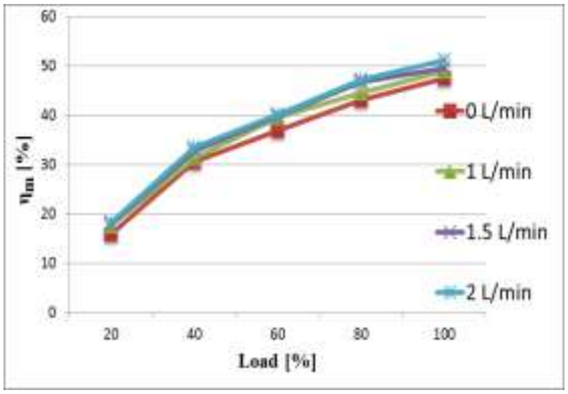

Figure 7: Load[%] vs ηm [%]

Conclusion: A single cylinder four stroke diesel engine was used to study the effects of different intake air oxygen enrichment levels on the performance characteristics. The following conclusions can be drawn from the investigations:

1) When the intake oxygen concentration was increased from 1 to 2 L/min, an improvement of up to 30% in BP can be achieved.

2) An average decrease of 10% in SFC can be obtained for the enrichment of 2 L/min oxygen.

3) Mean effective pressure increases up to 15% for the oxygen enrichment of 2 L/min.

4) An average of 12% increase in mechanical efficiency can be obtained from this OECT for the maximum enrichment level of 2 L/min.

5) An increased exhaust gas temperature of up to 20 ^{o}C can be achieved for the enrichment level of 2 L/min, which can be used to produce electrical energy using a thermocouple.

6) Since the required modifications in the existing intake system are not complex, an additional mixing chamber is necessary for the mixing of atmospheric air with the oxygen. Hence it is feasible. OECT provides a power boost continuously with high combustion efficiency and less SFC.

7)The stabilization of the engine was tested by running the engine for 200 hours with a break for 2 hours every 10 hours for servicing and refueling.

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Professional / Academic background:

Mr. Aakash Sirusshti[1] is currently pursuing his final year B.Tech in Mechanical Engg in SRM University, Chennai, India. He is quiet passionate on recent advancements in automobile and manufacturing technologies and hence finds himself more interesting to read a lot on these areas to improvise his knowledge. He is a part of the team in SRM university project design on ATV (Any Terrain Vehicles) wherein he has participated in a couple of auto expo competitions conducted across cities and also have won prizes. Apart from this, he has participated and presented couple of papers in many technical symposiums across many colleges.

Professional / Academic background:

Ms. Mirudhuneka Senthiil[2] is currently working as SAP Technical Consultant with IBM India Pvt Ltd, since 4.5 yrs for the client Saint-Gobain Industries. She has completed her B.E in Electrical and Electronics Engg in Coimbatore Institute of Technology in 2010 and Post graduated in MBA Human Resources Management from College of Engineering, Anna University, Chennai, India in 2014. She is already an award winner of a National level Hardware Design contest in Green Energy organized by Dayton University and PSG College in the year 2009. Apart from this she has presented a paper on Green SAP solutions for Manufacturing Industries in a couple of technical forums at IBM. She is very passionate to explore on wide areas in recent technological trends in all lines of Engineering and Management.

Professional / Academic background:

Dr. P.V Senthiil[3] is currently working as Prof & Head, Mechanical Engg at St Peter's University, Chennai, India. He lectures modules in CNC machines, Rapid Prototyping and AI & Robotics. He is also guiding 10 researchers in different disciplines. Dr. Senthiil’s work experience as a Factory consultant / knowledge transfer partnership associate working for electronic goods consumer industry in South Africa, France, UK. He was involved in developing, implementing & documenting operating procedures in advanced applications CNC industries for inventory reduction activities within various sectors of the company.

Prior to start of his research, Dr Senthiil was working as a Professor at Coimbatore Institute of Technology between May 1986 to Jun 2011. He did his masters in Mechanical Engineering at PSG Tech, April 1985, Bachelor’s at PSG Tech, in Mechanical Engineering, April 1983.

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