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REDUCTION OF SMOKE EMISSIONS FROM DI DIESEL ENGINE USING CATALYST BASED OXYGEN ENRICHMENT

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Abstract- Oxygen enrichment, one of the inlet air modification techniques, proves to be a promising technique in reducing smoke emissions from diesel engines. The main objective of the present work is to achieve reduction of smoke through catalyst based oxygen enrichment technique which proves to be an effective one as it utilizes air from the ambient to produce oxygen-enriched air. The catalyst used for the present study is zeolite and its unique shape provides a cage like structure which helps in trapping nitrogen molecules and thereby increasing the oxygen content in the air stream by Pressure Swing Adsorption (PSA). While conducting a bench test using zeolite pellets packed inside a module and blowing air through this arrangement, there was an increase in oxygen concentration from 21 – 22.5 % by volume. Based on the test result oxygen enrichment proves to be a better technique for reducing smoke emissions from diesel engines. The oxygen-enriching device can also be made compact and hence the need for oxygen cylinders is eliminated.

Keywords: *Pressure swing adsorption, Zeolite, oxygen Enrichment, Smoke*

I. INTRODUCTION

Research efforts worldwide are focused on improving the diesel engine’s performance and emission characteristics by using numerous combustion and exhaust after-treatment techniques. Several approaches such as the improvement of combustion and the development of after-treatment techniques have been attempted in the past in order to reduce smoke emissions (Soren et al 2002; Norimsa lida et al, 1986). With stricter emission regulations, the focus has been narrowed toward in-cylinder combustion enhancements. Among all the methods, the oxygen enrichment (fuel and air) and diesel particulate trap without modifying the engine design play a vital role in diesel engine smoke emission reduction (Yiannis et al 1990, 1991; Harry et al 1990, Subramanian and Ramesh, 2001). To improve performance and lower exhaust emissions further, one of the least exploited variables has been oxygen concentration in the combustion air, and it formulates the subject of current study.

A few studies were made in the past evaluating the effects of oxygen-enrichment on both direct injection and indirect injection diesel engines (Assanis et al, 2001; Douglas et al 2006, Marr et al ,1993 ;Poola and sekar,2003). Though many researches are being conducted on diesel engines using oxygen-enriched air, most of them simulated oxygen enrichment by mixing air stream with pure oxygen stored in cylinders. Thus there is a need of a device, which can directly produce oxygen enriched air from the ambient. This paper mainly focus on designing and fabricating such a device which is cost-effective and user-friendly. The present work is carried out in five phases:

1. (1) Selection of catalyst
2. (2) Preparation of catalyst
3. (3) Analysis of catalyst behaviour
4. (4) Performance and Emission Characteristics with and without Oxygen Enrichment

II. EXPERIMENTAL SETUP & MEASUREMENTS

The experiments were conducted on a 4.4 kW, Kirloskar make, Naturally aspirated, air-cooled, DI diesel engine which was made to operate with and without oxygen enrichment condition.

The injection timing was maintained at 23o BTDC through out the experiments. The engine was coupled to an electrical generator. The engine speed was maintained at 1500 rpm and fuel injection pressure at 200 bar. Airflow rates were measured with orifice meter. To improve mixing and to reduce pressure pulsations before the intake port, separate surge tank was installed for airflow. Chromel-alumel (K-Type) thermocouples connected to digital indicators were employed for the various temperature measurements which included exhaust gas temperature, Air inlet/outlet temperature of the module. A QROTECH emission analyser was used to measure the concentration of NOX and oxygen present in the exhaust gas. An MRU emission monitoring analyzer was used to measure the oxygen concentration in the inlet air.

The smoke intensity was measured using Bosch smoke meter.

III. EXPERIMENTAL INVESTIGATIONS

Variable load tests were conducted from no load to full load. The engine was sufficiently warmed up and stabilized before taking all the readings. The performance characteristics of the engine were evaluated in terms of brake thermal efficiency, brake specific fuel consumption and emission characteristics in terms of NOX and Smoke intensity.

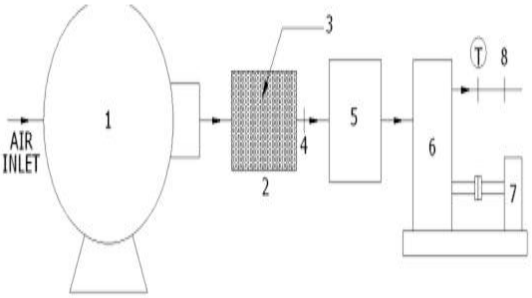

Figure 1 Schematic Diagram of the Experimental Setup

The blower was switched on when the catalyst was kept ready in the module. The speed of the blower was controlled using a regulator. The speed of the blower was generally kept considerably low so that the air flow gradually over the surface of the catalyst. The compressed air from the blower was admitted to the module where it gets enriched in oxygen concentration.

There are provisions after the module to measure the oxygen concentration in the inlet air with the help of an analyser. The detailed schematic line diagram of the experimental system with the oxygen enriching device is shown in Figure 1.

1.Blower, 2.Module, 3.Zeolite pellet 4. Enriched oxygen measurement, 5. Surge Tank, 6.Diesel Engine, 7.Electrical Alternator, 8.QRO-401 Emission Analyser, T- Temperature Measurement

a) SELCTION OF CATALYST

According to Peter et al (1993), zeolites are aluminosilicate minerals with complex crystal structures made up of interlocking rings of silicon, aluminium and oxygen ions.

The chemical composition of the zeolite used for oxygen separation is Na12 [(AlO2)12 (SiO2)12] 27H2O. It is the shape of zeolite that provides most of the ability to selectively adsorb nitrogen.

The zeolite used for oxygen production is shaped like a die with holes drilled on each face to form an internal cage. The corners of the die (providing the framework) are SiO2 and AlO2 units. Cations (either Na or Ca) are exposed throughout the crystal lattice.

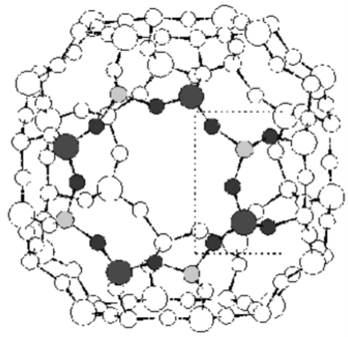

Figure 2 Structure of the zeolite used in Pressure oxygen production

Figure 3 Photographic view of Zeolite Swing Adsorption pellets used for PSA

When nitrogen is in close proximity to the exposed cations of the zeolite crystal, a charge induced dipole forms and the nitrogen is attracted into the zeolite crystal. Nitrogen is more polarisable than oxygen and the zeolite selectively adsorbs nitrogen allowing the oxygen gas to pass unrestricted.

The internal surface area of zeolite is extremely large and so provides a high degree of adsorption per volume of zeolite. The cage like structures of zeolite have been carefully designed to allow only nitrogen to pass to their inside and to exclude the larger oxygen molecules.

That is, the holes in the side of the zeolite dice are large enough to allow nitrogen entry but small enough to exclude oxygen. The uniformity of the micro pores is the major advantage of synthetically produced zeolites. The structure of the zeolite and photographic view of the zeolite catalyst used in Pressure Swing Adsorption (PSA) oxygen production is shown in Figure 2 and 3.

b) Simulation of Pressure Swing Adsorption

Pressure Swing Adsorption was simulated in the laboratory using a blower. The catalyst was packed in a module made of PVC pipe, through which air was blown at 2 bar. An emission monitoring analyser was used to measure the oxygen content down stream of the module. The PSA process involves pumping air above 1.5 bar through blower in which a bed containing a filter medium that preferentially adsorbs nitrogen, while allowing oxygen to pass through unrestricted. The adsorbed nitrogen is then flushed away by a proportion of the oxygen enriched air.

The oxygen concentration was displayed on the analyser display unit. The oxygen concentration initially decreased, because the oxygen was adsorbed initially. After sometime, the concentration gradually increased. This was due to desorption of oxygen by the catalyst. This method yielded an increase in oxygen content from 21 – 22.5 % by volume as shown in the Figure 4.

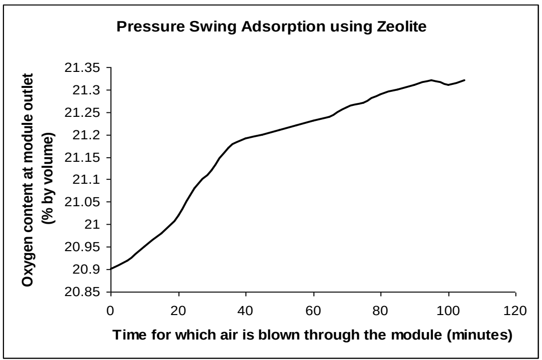

Fig.4. Variation oxygen concentrations with time for PSA

IV. PERFORMANCE & EMISSION CHARACTERISTICS

Based on the oxygen enrichment obtained from the catalyst based oxygen enrichment technique, the experiments were conducted on the test engine and the performance and emission characteristics were evaluated.

The variation of brake thermal efficiency with power output with oxygen enrichment is compared to that without oxygen enrichment and is shown in Figure 5. It can be seen that the brake thermal efficiency does not change at no load and 25% load conditions. As the load increases, the brake thermal efficiency also increases gradually from the baseline conditions. This is because as the load conditions increase, the amount of fuel injected also increases. In the oxygen enriched condition due to availability of more oxygen, combustion is more complete and hence the output power for a given quantity of fuel increases. The brake thermal efficiency is more than the baseline conditions at 75% load on the engine.

The variation of BSFC with engine load is depicted in Figure 6. It can be seen that as the load increases, the brake specific fuel consumption is found to decrease. When compared with the baseline values, the BSFC in the oxygen enriched condition is lesser. This is because the enriched oxygen increases the combustion rate that reduces the quantity of fuel consumed compared to the baseline condition.

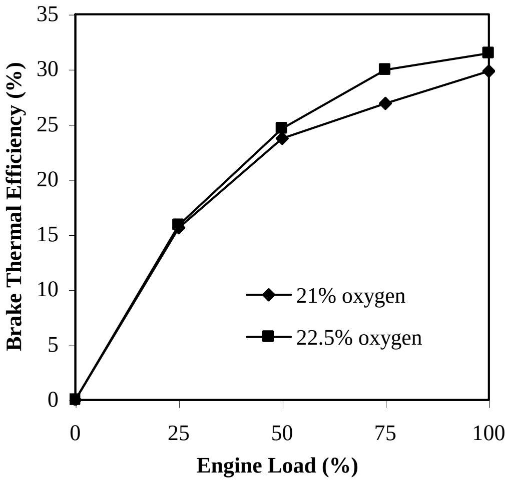

Fig.5. Effect of oxygen enrichment efficiency consumption

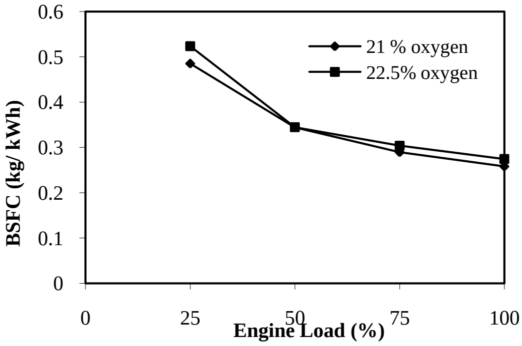

Fig.6. Effect of oxygen on Brake thermal Brake Specific fuel

Figure 7 shows the variation of smoke intensity with engine load with and without oxygen enrichment. It can be seen from the figure that the smoke intensity is almost similar from no load to 50% load conditions. Then a sudden increase in smoke intensity is seen at full load conditions with normal operation of the engine. This is due to incomplete combustion of the fuel at higher load conditions. In the oxygen enriched condition, there is a gradual increase in smoke intensity which is far lesser than that of baseline conditions. This trend is mainly due to increased oxygen content available for combustion. The smoke intensity at full load conditions reduces to 25% of that in the baseline condition.

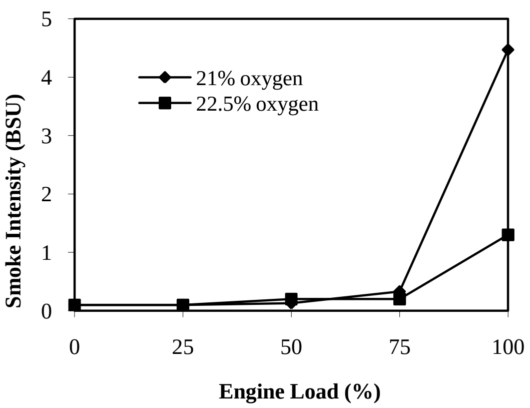

Fig.7.Effect of oxygen enrichment on Smoke Intensity emissions

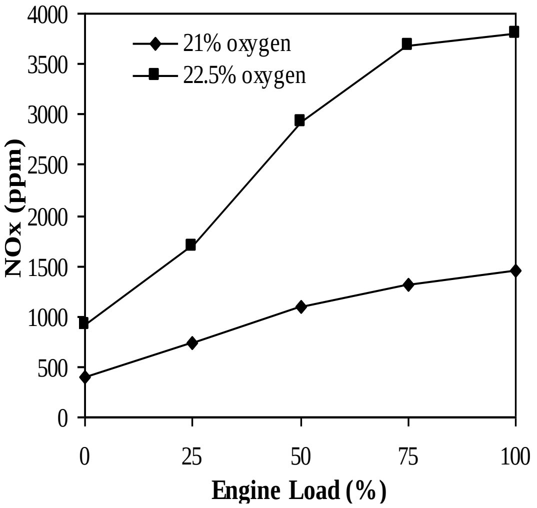

Figure 8 Effect of oxygen enrichment on NOX emissions

Figure 8 shows the variation of NOX emissions with engine load with and without oxygen enrichment. NOX formation is favoured by increase in combustion temperature, increase in oxygen concentration and advance in the fuel injection timing. In this case, due to the availability of more oxygen, combustion is more complete and hence the combustion chamber temperature increases. This combined with increased oxygen quantity favours NOX formation. As predicted, due to the availability of more oxygen for combustion the NOX content increases with the load conditions. The NOX content is almost doubled from the baseline even at no load conditions with the availability of more oxygen. This trend continues and at full load, the NOX content is almost four times as that of the baseline.

V. CONCLUSION

Experiments were conducted with a single cylinder, direct injection, naturally aspirated, four-stroke cycle diesel engine. Significant conclusions were drawn based on the experiments conducted are given below:

1. The catalyst which was selected and prepared was able to enrich the oxygen content in air from ambient 21 – 22.5% by volume.
2. Oxygen enrichment proved to be better for reduction of smoke intensity which was reduced to one-fourth of the baseline.
3. The NOX emission levels increased from 500 ppm (baseline) to around 4000 ppm in oxygen enriched condition.
4. By optimizing the fuel injection timing along with percentage of oxygen enrichment, simultaneous reduction of smoke and NOX can be achieved.

REFERENCES

1. Soren Andersson, Claes Akerlund and Micael Blomquist (2002), 'Low pressure EGR calibration strategies for reliable diesel particulate filter regeneration on HDD engines', SAE 2002 –01-2780.
2. Norimasa Iida, Yasutoshi Suzuki, Takeshi Sato. G, Takashi Sawada, 'Effects of Intake Oxygen Concentration of Particulate Emissions from a D.I. Diesel Engine', Paper no. 861233
3. Yiannis A. Levendis, Kevin McInerney, Thomai Panagiotou (1991), 'Evaluation of a Self-Cleaning Particulate Control System for Diesel Engines', International Congress and Exposition, Detroit, Michigan, February 25-March 1, 1991, SAE Technical Paper Series, Paper no. 910333, pp. 183-193
4. Yiannis A. Levendis, Thomai Panagiotou, and Mohammad E. Tasilm (1990), 'Development of a Self-Cleaning Particle Trap for Diesel Engine Particulate Control', International Congress and Exposition, Detroit, Michigan, February 26 — March 2, 1990, SAE Technical Paper Series, Paper no. 900601, pp. 195-201
5. Harry C. Watson, Eric E. Milkins, Geoff R. Rigby (1990), 'A New Look at Oxygen Enrichment 1) The Diesel Engine', International Congress and Exposition, Detroit Michigan, February 26 — March 2,1990, SAE Technical Paper Series, Paper no. 900344, pp. 1-18
6. Subramanian. K. A and Ramesh. A (2001), 'Experimental Investigation on the use of Water Diesel Emulsion with Oxygen Enriched Air in a DI Diesel Engine', SAE 2001 World Congress, Detroit, Michigan, March 5-8, 2001, SAE Technical Paper Series, Paper no. 2001-01-0205
7. Assanis. D. N, Poola. R. B, Sekar. R, Cataldi. G. R (2001), 'Study of Using Oxygen-Enriched Combustion Air for Locomotive Diesel Engines', Journal of Engineering for Gas Turbines and Power, January 2001, Paper no. DOI: 10.1115/1.1290590, Vol. 123, pp. 157-166
8. Douglas E. Longman, Roger L. Cole, Suresh K. Aggarwal (2006), 'In-Cylinder Injection of Oxygen-Enriched air to reduce Diesel Exhaust Emissions', Proceedings of ICES2006, ASME Internal Combustion Engine Division 2006 Spring Technical Conference May 8-10, 2006, Aachen, Germany, Paper no. ICES2006-1445, pp. 1-8
9. Marr. W. W, Sekar. R. R, Cole. R. L, Marciniak. T. J, Longman. D. E (1993), 'Oxygen-Enriched Diesel Engine Experiments with a Low-Grade Fuel', Fuels and Lubricants Meeting and Exposition, Philadelphia, Pennsylvania, October 18-21, 1993, SAE Technical Paper Series, Paper no. 932805, pp. 1-6
10. Poola. R. B, Sekar. R (2003), 'Reduction of NOX and Particulate Emissions by Using Oxygen-Enriched Combustion Air in a Locomotive Diesel Engine', Journal of Engineering for Gas Turbines and Power, April 2003, Paper no. DOI: 10.1115/1.1563236, Vol. 125, pp. 524-533
11. Kent N. Hutchings, Merill Wilson, Paul A. Larsen, Raymond A. Cutler (2006), 'Kinetic and thermodynamic considerations for oxygen absorption/desorption using cobalt oxide', Solid State Ionics, Vol.177 (2006), pp. 45 – 51
12. Peter Scott, 1993, (IChem Ltd.) 'Oxygen - Pressure Swing Adsorption', Ruthven. D, Farooq. S and Knaebel. K (1993) Pressure Swing Adsorption; VCH New York; Whiting, R. Chemistry in New Zealand; Vol. 55, No 2, 1991

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