STUDY OF USE OF ENRICHED AIR IN C.I.ENGINES

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Abstract

Nowadays the diesel engines are most promising devices in the field of transportation and power sector. Performance of any heat engine is mainly based on the complete combustion of fuel inside the engine cylinder. Complete combustion of fuel depends on the availability of oxygen inside the engine cylinder and mixture strength. The air, which is supplied to the engine, contains lot of impurities like sulfur, nitrogen, and carbon Di oxide etc. these impurities affects the performance, and exhaust emissions. The air fuels mixture before combustion and the burned gases after combustion is actual working fluids. Supplying extra oxygen in the combustion chamber for complete combustion of fuel is one method, which will reduce HC, CO and smoke and could improve the brake thermal efficiency. It will also affect the formation of NO_x directly and indirectly. A brief technology assessment will uncover the advantages and problems associated with quality of air supplied to the engine. In present work, performance and emission characteristics of single cylinder diesel engine with effect of intake oxygen air enrichment investigated. Added oxygen in combustion air leads to shorter ignition delay and offers more potential of burning diesel. Oxy-fuel combustion reduces the volume of fuel gases and reduces the greenhouse effect also. During study of available material it is found that oxygenated air is an effective method for reducing PM , CO, HC,

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1. Introduction

Today's conventional internal combustion engine uses only air as it is necessary for combustion process. Diesel engines are more efficient, so they are widely used in power plants and automotive applications. This results in loss of efficiency of that particular internal combustion engine Air is mixture of various gases which results in loss of heat energy produced by combustion due to undesired combustion of undesired gases However, diesel engines emit smoke, nitrogen oxides that are difficult to meet stringent emission regulation through engine design, high- grade conventional fuels and catalytic systems. NO_x and smoke emissions from diesel engines are considered to be resulting from the heterogeneous air -fuel mixture, particularly the existence of stoichiometric regions and fuel rich regions in the mixture. However in spite of advantages NO_x and smoke emissions from the diesel engines cause serious environmental problems. All polluting exhaust gases form due to incomplete combustion of diesel fuel Reducing the pollution of automobile emission and studying the application of an automobile alternate fuel are crucial subjects in the field of automobiles at present. With the constant increase in high-grade highway mileage and the significant improvement in production technology of the high-speed diesel engine and the increasing need for heavy-duty trucks for transportation, the number of diesel vehicles is increasing. Many cities in China have prohibited the running of diesel vehicles in urban areas because diesel automobiles have heavy smoke emission and loud noise and people feel that diesel automobiles are very harmful to the environment. Therefore, reducing the smoke emission of diesel automobiles, especially to used diesel automobiles, has become a problem that calls for an urgent solution. Smoke emission can be largely reduced if diesel vehicles are changed to fuel with dual fuel, which is one of the efficient ways to reduce the smoke emission of diesel vehicles.

1.1 Literature Review

To study the effect of oxygen enriched air on performance characteristics of diesel engine. We referred research papers .Mohammed Fahe, had used oxygen enriched combustion (OEC) technology with high emission fuels. The conclusions are oxygen enriched intake air should be used to reduce the amount of stack gas CO emissions. Flue gas reduction and Energy efficiency turn down ratio & flame stability. Kuppusamy and Palanisamy, investigate the effect of using oxygen enriched air on Diesel engine exhaust emission. And made conclusion that are 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. Mattias Nyberg &Lars Nielsen , Diagnosis of the air intake system of an SI-engine. Modeling concepts, residual generation and evaluation. System based on non-linear semi-physical model and use of different residual generation method. And concluded that increases performance of engine. Model based system appropriate. Fredrik Norman, are investigated. The possibility of high-temperature reduction of nitrogen oxides (NO_x) in oxy-fuel combustion. It is concluded that an efficient high-temperature reduction of NO_x is achieved with high-purity oxygen, negligible amount of air ingress, presence of a sub stoichiometric Combustion zone, and relatively long residence time. K.RAJKUMAR , have studied Added oxygen in the combustion air leads to shorter ignition delays and offers more potential for burning diesel. And different parameters such as like Ignition delay, Combustion duration, Heat release and Cylinder pressure was discussed. S.Sreenatha Reddy, have achieved 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)., 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.

1.2 Emission Characteristics of C.I. engine

The combustion process in CI engine occurs only at the interface between the injected fuel system and air compressed in the cylinder. Thus, oxidation of fuel is not always complete. The incomplete combustion of the fuel produces CO, HC and oxygen containing compounds such as aldehyde. In addition, the temperature in the cylinder during combustion also promotes the production of NO_x from nitrogen and oxygen in air, the equivalence ratio plays an important role in the control of engine emissions (Rehman A. et.al) It is defined as the actual fuel-air ratio divided by the stoichiometric fuel-air ratio, at very low value NO_x can be significantly reduced. If the fuel air mixture becomes very lean then it becomes increasingly more difficult to ignite. (Pundir B.P). The most familiar emissions from a C.I. engine are the characteristic smoke produced when engine operates under load. White smoke can be produced when the fuel injection is initiated too late during the cycle or when compression ratio is too low. Blue smoke is typically caused due to excessive lubrication oil entering in the combustion chamber because of poor piston ring, sealing and valve guide wear. Gray-blue smoke is typically generated when the engine is operating at or near full load and too much fuel is injected or when air intake is partially obstructed. Heavy smoke from an engine usually indicates a loss in thermal efficiency, power output and fuel economy. Gray-black smoke results from poor maintenance of air filter and fuel injectors or from improper adjustment of the fuel injection pump. The chemical composition of fuel, cetane number and volatility affect gray-black smoke production in diesel engines. (Karim and ward), experimented by varying the oxygen concentration from 15% to 55% by mass. They concluded that the increased concentration of oxygen in the inlet air resulted in a drastic reduction of smoke density at very high oxygen concentration was observed due to reduced ignition delay. (Watson et. al), conducted experiments with oxygen - enriched air (up to 30% O_2 by volume). They achieved about 80% reduction in smoke at full load and 5% to 12% increase of thermal efficiency and a decrease CO and HC emissions. However, NO_x increased due to the increase of oxygen concentration and cycle temperatures. (Donahue and Foster), concluded that oxygen enrichment increases No_x through increased temperatures and oxygen concentration. It decreases particulate through reduced fuel pyrolysis and increased soot oxidation. Increased oxygen concentration had a thermal and dilution effect on No_x emissions and it was concluded that optimizing the injection timing could have further improvement.

2. Materials and Methods

2.1 Experimental set-up:

Diesel engines are widely used for various applications ranging from agriculture to automobiles. Engines are required to be tested mainly for purposes Firstly, on a production line of engines; engines are tested to check the proper operation, output, fuel consumption etc. and secondly, in research or design purpose, where the performance of new design is to be evaluated. Equipment consists of a single cylinder, vertical diesel engine mounted over a sturdy frame. Dynamometer 3.5 KVA capacity D.C. generator coupled to the engine and water rheostat used to load the engine. A digital multichannel temperature indicator used to measure temperatures at various points. Various measurements provided enables to evaluate the performance of the engine at various loads.

Table 1: Test Engine Specifications

Make	*Kirloskar*
Class	Single cylinder, 4-stroke direct injection type
Power output, kW	5.2
SFC, g/kWh	251
Speed, rpm	1500
Fuel	High speed diesel
Bore, mm ϕ	87.5
Stroke mm	110
Swept volume, cc	661
Compression ratio	15:1
Dynamometer	Electrical alternator

Table 2. Exhaust gas analyzer specifications.

Exhaust Gas	Measuring range	Resolution	Accuracy
CO	0-10 vol.%	0.01 vol.%	<0.6%vol.:±0.03%vol.≥0.6%
			Vol.: ±5% of ind.val.
HC	0-20,000 ppm	≤2000:1ppm vol.	<200 ppm vol.: ±10ppm
		>2000:10ppm	vol.≥200ppm vol.:± 5% of ind. Val.
CO_2	0-20 vol.%	0.1 vol.%	<10% vol.:± 5% vol..≥10%
			vol.:± 5% of val.M
O_2	0-22 vol.%	0.01 vol.%	<2% vol.:± 0.1% vol. ..≥2%
			vol.:± 5% of val.M
NO	0-5000ppm	1ppm vol.	<500 ppm vol.: ±50ppm vol.

			≥500 ppm vol.: ±10% of ind. Val..

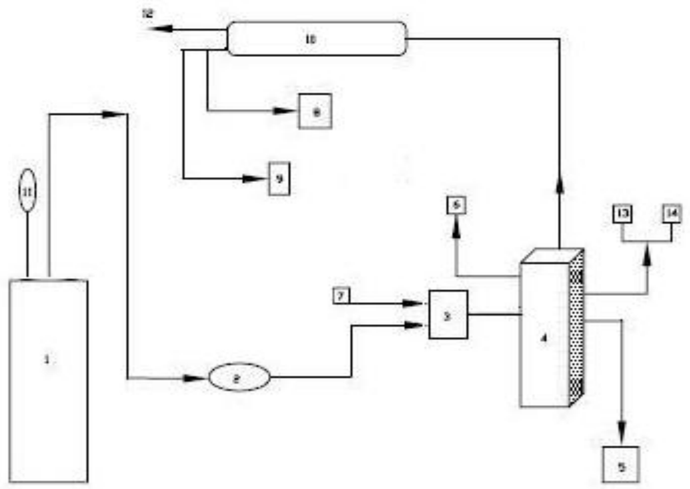

Figure 1. Experimental set –up

1. Oxygen Cylinder
2. Gas Flow meter
3. Mixing chamber
4. Kirloskor engine
5. Coolant water thermometer
6. Exhaust gas thermometer
7. Orifice meter
8. NO_x meter
9. Smoke meter
10. Exhaust
11. Pressure guage
12. To atmosphere
13. Deisel tank
14. Jatrapha at tank

2.2 Engine Modification and Measurements

The experiment of performance and emission characteristics were conducted on a typical four-stroke, single cylinder, constant-speed, water -cooled, direct-injection diesel engine. The engine coupled with an electrical dynamometer, used for loading the engine. Tests were conducted at no-load, 20, 40, 50, 60, 80, and 100% of rated load. Engine speed was maintained at 1500 rpm (rated speed) during all experiment. Fuel consumption, inlet air flow rate and exhaust temperatures were measured. The smoke opacity of the exhaust gases was measured by AVL Exhaust gas analyzer and smoke opacimeter (Make AVL Austria; Model: 437), detail specification given in table 02. Calibrated fuel burette used for fuel consumption measurement. Orificemeter fitted to air inlet tank with water manometer for air intake measurement. Multichannel digital temperature indicator fitted for temperatures measurements at various points. Exhaust gas calorimeter used to measure heat carried away by exhaust gases. An air tank fitted with an orifice connected to the air- induced manometer. A thermocouple connected to the exhaust manifold of the engine to measure exhaust gas temperature, and two thermocouples were used to measure the inlet and exhaust coolant temperatures. The mixing chamber that helped in mixing oxygen and air in the inlet manifold during the suction stroke was fabricated. Additional oxygen was supplied from a cylinder to enhance the oxygen concentration in the engine intake manifold. A gas flow meter was used to measure its flow rate. The engine was allowed to reach steady state and the various readings were noted down. The same procedure was followed to get readings after additional oxygen supply on the engine through the mixing chamber. The oxygen flow rate was varied from 2cc/s to 2.7cc/s corresponding to about 15% of full load air consumption of the base engine and 2.7cc/s corresponding to about 20% of the full load consumption of the base engine. The effect of oxygen enrichment on the various parameters, such as brake thermal efficiency, specific fuel consumption, smoke, heat lost in exhaust and heat lost in cooling water was determined.

3. Result and Discussion

Reducing sulfur not only reduces SO_2 emissions in diesel vehicles, it can also significantly reduce particle emissions. In the oxygen, rich exhaust of diesel vehicles several percent of the SO_2 formed during combustion is oxidized to SO_3, which dissolves in the water vapor present to form sulfuric acid (H_2SO_4) vapor. H_2SO_4 is one of the few substances that are capable of homogenous nucleation, which, aside from soot formation, appears to be the primary mechanism for initiation of ultra fine particle formation in diesel exhaust, producing newly formed particles of around one nm. Even though sulfate particles account for only a small fraction of particle volume or mass, it can account for a large fraction of particle numbers. Moreover, sulfate nano particles provide a relatively large surface area onto which HC species condense, resulting in particle growth and increasing particle toxicity. Even without the benefit of additional emissions controls, reducing sulfur levels in diesel fuel leads to lower total PM emissions and a substantial decrease in the mutagenicity and toxicity of the particulate matter formed. A variety of testing opportunities have supported this conclusion. Reduction in fuel sulfur levels from 440 to 70 ppm led to a 56% reduction in numbers of particles emitted from diesel vehicles. In addition to these primary PM emissions, SO_2 emissions can lead to secondary particle formation, as particles form in the ambient air. EPA models estimate that over 12% of SO_2 emitted in urban areas is converted in the atmosphere to sulfate PM. Approach is to emissions control requires a series of diesel engine modifications including fuel injection, electronic engine controls, combustion chamber modification, and air handling characteristics, reduced oil consumption, turbo charging, injection retard, exhaust gas recirculation (EGR), and reduced heat rejection. Efficient combustion through improved mixing of air and fuel results in lower HC and smoke emissions. Electronic control of fueling levels and timings, combined with high-pressure fuel injection system, can be quite beneficial. Turbo charging increases NOx emissions but reduces particulates. Charge cooling (cooling the intake of air after the turbo chargers) directly reduces NOx emissions by reducing peak cycle temperature and pressures. Injection retard is the most effective way of reducing NOx emissions, but increases fuel injection, smoke, and HC emissions, particularly under light loading. EGR cam significantly reduces NOx but may double particulate emissions. Effective control of lubrication oil through engine design prevents it from entering the engine piston rings, valve guides, is turbo chargers and has been shown to reduce HC emissions by about 50 % In order to achieve low level of particulate emissions. Manufacturer has also developed exhaust treatment devices that are added to clean up the exhaust after it leaves the engine. Several devices are being evaluated. One is the flow through catalytic converter designed to operate on low sulfur fuel. This may reduce the soluble organic fraction of particulates by as much as 90 % and may reduce the carbon portion. Based on experimental data we observe the variation in brake thermal efficiency, specific fuel consumption, smoke, NO_x, exhaust heat lost in cooling water with respect to brake power. The variation of specific fuel consumption (SFC) at various power outputs of the base engine is compared with the modified engine at increased oxygen flow rates. There is a fall in the SFC at all loads when the oxygen flow rate is enhanced. This decrease is due to increase brake thermal efficiency with enhanced oxygen flow rate.

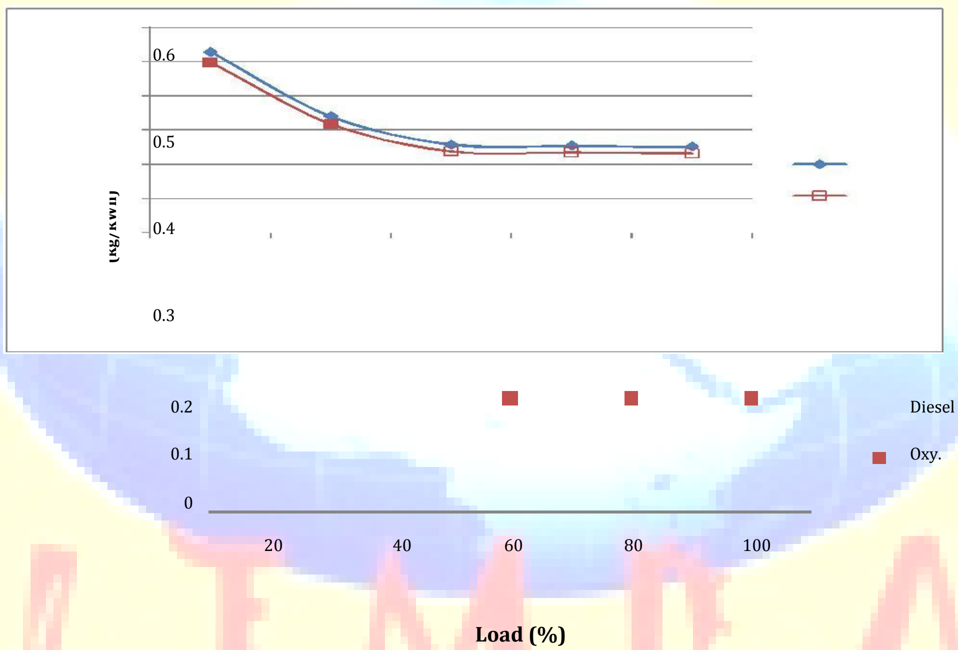

Figure 2. Effect of power on BSFC

The variation of brake thermal efficiency at various power outputs of the base engine compared with different oxygen flow rates. The condition where atmospheric air was used designated as normal operation. There is an improvement in the brake thermal efficiency at all loads when the oxygen flow rate enhanced. Thus, improvement is mainly due to better combustion with Oxygen, but brake thermal efficiency falls as the oxygen flow rate is increased to 2.7 cc/s. Smoke levels drastically decreases with increase in oxygen flow rate at all loads due to better oxidation of soot.

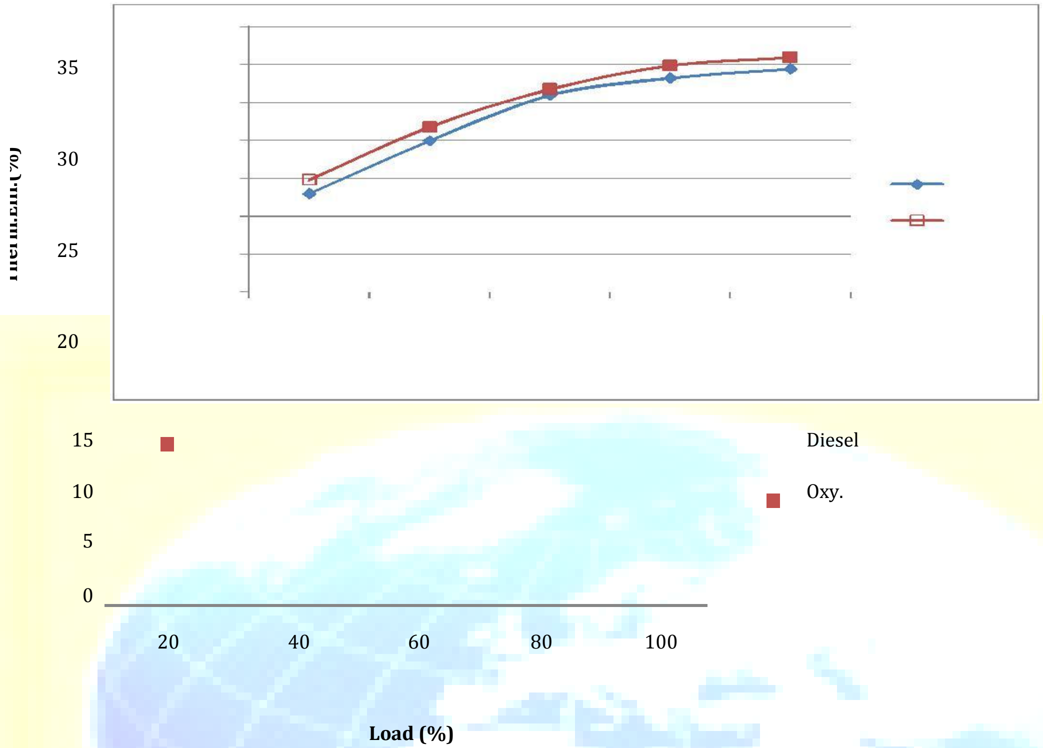

Figure 3. Effect of power on brake thermal efficiency percent

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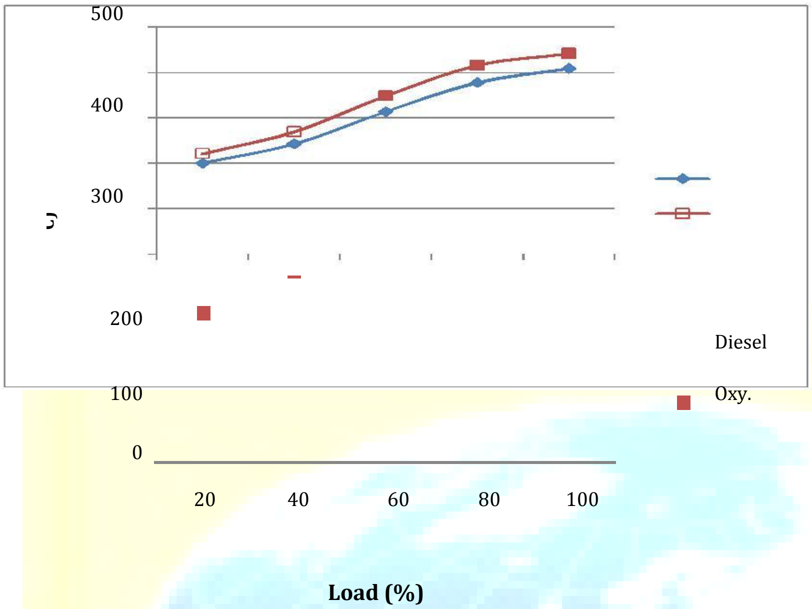


Figure 4. Effect of Load percent on exhaust gas temperature

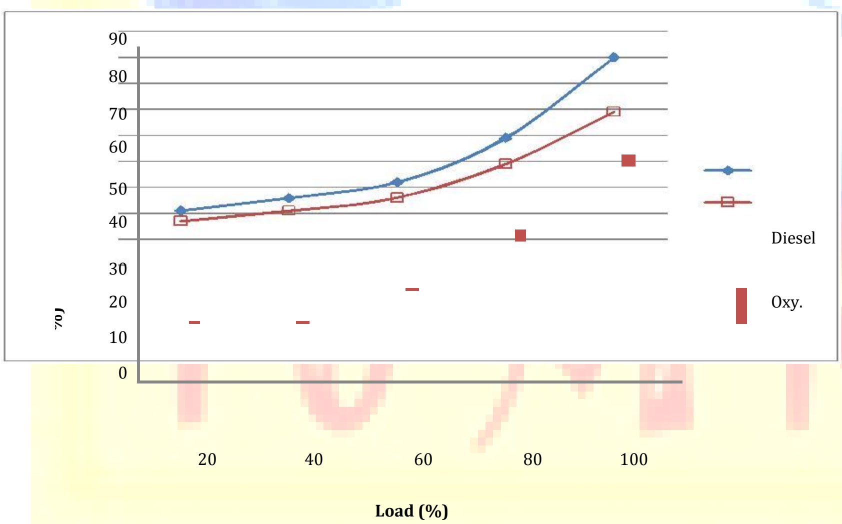
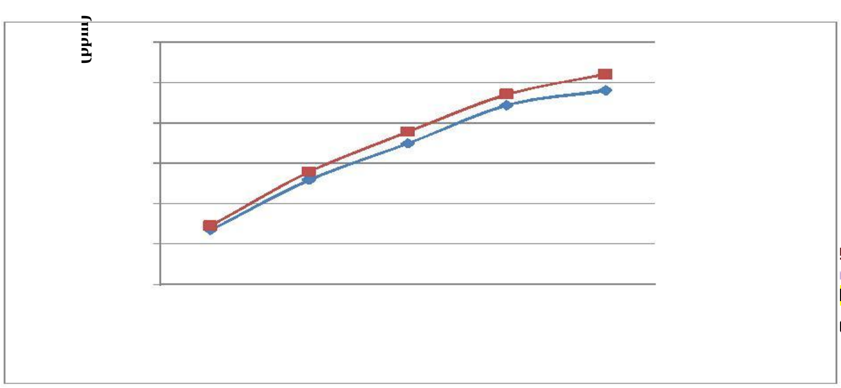


Figure 5. Effect of Load percent on Smoke



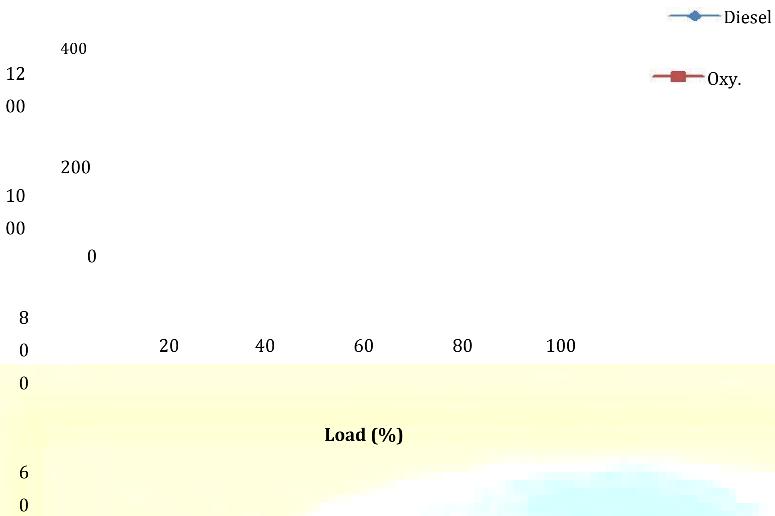


Figure 6. Effect of Load percent on NOx emission

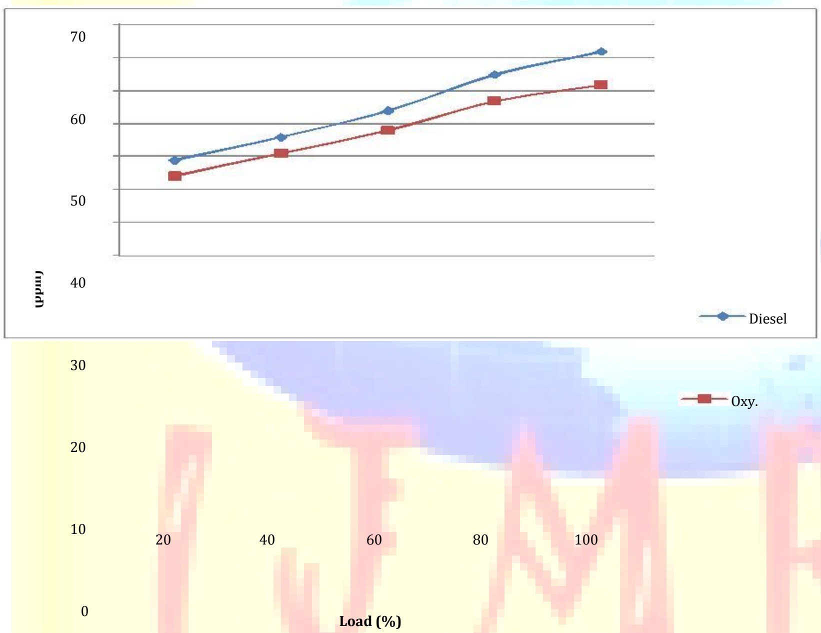


Figure 7. Effect of Load percent on HC emission.

1. **Effect of load percentage on brake specific fuel consumption.** From the fig.02 shown here, it is evident that b.s.f.c lower for diesel engine operating on oxygenated air, this improvement is due to high combustion rate with oxygen enriched air. Reduction in fuel consumption 8.3 % observed

2. **Effect of load percentage on brake thermal efficiency.** From the fig. 03 it has been observed that there is increase in brake thermal efficiency at all the load. Increased thermal efficiency due to better combustion characteristics of diesel due to presence of oxygen inside the combustion chamber which promotes burning of unburnt fuel. Brake thermal efficiency increases from 29.5% to 31%; i.e. increase in Brake thermal efficiency 1.5% when engine operated on oxygen-enriched air.

3. **Effect of load percentage on exhaust gas temperature.** Fig.04 shows the Effect of enriched O_2 on combustion results in lower exhaust gas temperature. There is decrease in the exhaust heat at all loads when the oxygen flow rate is increased. The decrease in exhaust heat may be due to more heat being liberated due to better combustion in the combustion chamber. This would have resulted in lower heat in the exhaust. There is a rise heat in coolant at all loads when the oxygen flow rate in the heat is increased. The benefits of increase in thermal efficiency decrease in fuel consumption, and smoke emission etc change adversely when the oxygen flow rate is increased to 2.7cc/s. At higher oxygen flow rates the mixture becomes relatively, richer compared to the base engine operation and this would have affected the combustion adversely.

4. **Effect of load percentage on smoke emission.** From Fig.05, it is observed that smoke opacity increases with engine load. Lower Smoke opacity may be due to better oxidation of soot because oxygen enriched air improves diffusion combustion process.

5. **Effect of load percentage on NOx emission**. It is obvious from the fig.06 that the increase of NOx emissions at all the loads. There is increase 7.76 % in NOx emission observed at full load. Increase in NOx emissions due to increase of the cylinder gas temperature.

6. **Effect of load percentage on HC emissions.** From the fig.07, it can be seen that HC emission reduces by using oxygen enriched intake air in diesel engine. Reductions in HC emissions due to enhanced diffusion combustion fraction while compared to oxygen enriched air and normal diesel operation, which promotes complete combustion.

7. **Effect of load percentage on CO emissions.** From the fig.08 it has been observed that there is reduction in CO emission at all loads. This reduction shows the better combustion phenomena of the oxygen enriched intake air engine performance. This reduction is good signal for environmental protection through global warming.

4. Conclusions

We have referred different papers. There are different methods for the enrichment of the oxygen such as air separation membrane, using the pressure adsorption theory (PSA) with the help of the zeolite, with the help of the different additives such as karanja oil, etc. But among all these methods the enrichment of the oxygen with the help of the separate oxygen cylinder is the most convenient method. With help of this method we will get the enrichment in the oxygen level. And because of this there is complete combustion will be occur which may enhance the power. Significant conclusions based on experiments conducted are given below: A comparative study was conducted on the effectiveness of promising technique regarding reduction in exhaust emission while improving engine operating parameters oxygen enrichment of intake air. Oxygen enrichment of the intake air may be a method for power boosting with subsequent improvement in power density. Additionally the oxygen concentration of the intake air can be readily increased to high levels, hence providing the opportunity to drastically decrease soot, CO and HC emissions. None the less, this increase of oxygen content of intake air along with increase of the cylinder gas temperature can cause dramatic increase of NOx emissions. Therefore, the extent of oxygen enrichment of intake air should be limited. It is concluded that oxygen enrichment of the in performance and a drastic reduction in smoke of a diesel. However, it will have an adverse effect on No_x emissions. Thus, it has to be combined with other methods of controlling No_x emissions if an overall improvement is desired. Even through the particulate emission are reduced the existing method fails in controlling No_x emission. The increase in No_x emission is due to increase in stem temperature. Hence experiments may be carried out in such a way that decreases the combustion temperature and simultaneously with out increasing smoke concentration. Method, such as, exhaust gas recirculation, injections of water/fuel emulsion and after cooling following turbo, charging may be tried.

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