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Performance Analysis of a Diesel Engine Using Oxygen Enriched Combustion

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ABSTRACT

IC engine has an effective efficiency of 30-35%. This means that almost 70% of the chemical energy contained in the fuel is lost in the coolant, in the exhaust gases, in the incomplete combustion of fuel and in radiation. One way of increasing efficiency is by inducting oxygen into the combustion chamber since oxygen is a combustion enhancer. If the amount of oxygen entering into the combustion chamber increased it would result in better engine performance and lower emissions. Oxygen can be inducted in the intake manifold by the help of an external source. This additional increase of oxygen in air will affects all

parameters of the engine like Brake power, emissions, and heat release. In this study only performance characteristics of the engine are considered. Load test is conducted on a single cylinder diesel engine for various concentration of oxygen and the engine performance parameters are discussed.

Keywords: Efficiency, Chemical Energy, Combustion Chamber, Performance.

I - **Introduction**

There are many techniques to improve the performance of compression ignition Engines as given below

A) Engine Modification
B.Effect of Injection Pressure And Timing
.C.Effect Of Compression Ratio .
D.Effect of Multiple Injections.
E.Effect of Thermal Barrier Coating.
F.Effect of Nano Additives.
G.Effect of Metal Based Additives.
H.Effect Of Oxygenate Additives.
I) Effect Of Antioxidant Additives.
J) Effect of Alcoholic Additives.

OXYGEN ENRICHED COMBUSTION:

1. INTRODUCTION:

Diesel engine always operated in excess air conditions hence air entering has about 78% Nitrogen, 21% Oxygen and 1% other gases. Improving engine performance and reducing pollution has always been a problem because higher operating temperature would result in better engine performance but will lead to NO_x emission. To improve the performance and fuel economy of the engine of the engine nitrogen getting into the engine has to be eliminated.

If enough air is supplied to the fuel during combustion, carbon dioxide (CO_2) will appear in the products plus release of heat, and if the supplied air is exactly the theoretical air needed then the exhaust gaseous products consists of 21% carbon dioxide (CO_2), about 78%

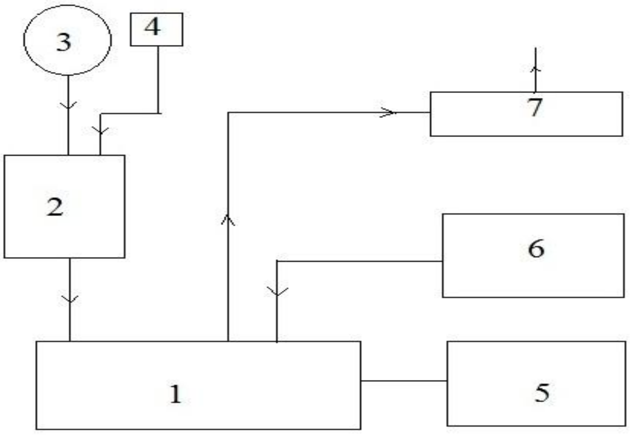
Nitrogen, and 1% of various gases, plus release of heat. When the air supply is not sufficient the carbon partially is burnt to carbon monoxide (CO) and the full calorific value of the fuel will not released, this is known as incomplete combustion which is one of the combustion process main sources of heat losses.

There are many contributing reasons to why a combustion process becomes incomplete in an actual case. One of the easiest reasons to see is that a lack of oxygen leaves some of the fuel unburned. But also incompletion can be attributed to insufficient mixing between fuel and oxygen in the combustion chamber due to the short time intervals in which these combustions are occurring. Another cause for incompletion is because of a process called hydrogen bonding. Hydrogen bonding is a process in which chemical bonds form between molecules containing a hydrogen atom bonded to a strongly electronegative atom (an atom that attracts electrons). Because the electronegative atom pulls the electron from the hydrogen atom, the atoms form a very polar molecule, meaning one end is negatively charged and the other end is positively charged. Hydrogen bonds form between these molecules because the negative ends of the molecules are attracted to the positive ends of other molecules, and vice versa. To overcome the said problem 100% oxygen in the intake can be given which would result in zero NOx emission. But this method has a lot of limitation. Secondly the nitrogen entering into the engine can be replaced by different kind of gas (eg: Inert gas) in the intake system so that it doesn’t interact with the combustion process and should not be a pollutant to the performing system or to the environment. These both methods have serious limitations. Another way of doing this is by increasing the percentage of oxygen in the intake air which will effectively replace the nitrogen from getting into the engine. This will serve as a suitable alternative.

The concept of oxygen enrichment aims at limited substitution of the nitrogen in air by oxygen to achieve low emission levels. Because of the increased oxygen content, additional fuel is burned. Oxygen-enrichment of combustion air provides an opportunity to achieve ignition with minimum amounts of premixed fuel because it reduces the ignition delay period under all operating conditions. Increasing the oxygen content with the air leads to faster burn rates and the ability to burn more fuel at the same stoichiometery. Added oxygen in the combustion air leads to shorter ignition delays and offers more potential for burning diesel.

2 EXPERIMENTAL SETUP:

Test engine used in the experiments is a single cylinder four-stroke, naturally aspirated, constant speed compression ignition engine. The experimental set-up is shown in block diagram in Figure 1. Engine was tested at a rated speed of 1500 rpm. The readings taken during each set of experiments was used for the calculation of brake specific consumption, thermal efficiency, and other engine characteristics. The type of experiment is a study state engine test. Application of loads included five levels: 0%, 25%, 50%, 75%, and 100% loads.



(1)ENGINE;(2)MIXING CHAMBER;(3)OXYGEN CYLINDER WITH FLOW METER;(4)AIR FROM ATMOSPHERE;(5)LOADING DEVICE;(6)FUEL TANK;(7)EXHAUST GAS TO ATMOSPHERE

Figure:1 Experimental Setup

3. ENGINE SPECIFICATIONS:

Make	Kirloskar
BHP	5HP
Speed	1500 to 2000 rpm, governed speed of 1500 rpm
Power	3.7KW
No. Of Cylinders	One
Compression Ratio	17:1
Bore	80 mm
Stroke	110 mm
Type Of Ignition	Compression Ignition
Method Of Loading	Rope Brake Dynamometer
Method Of Starting	Manual Crank Start
Method Of Cooling	Water

Table 1: Engine Specifications

4. OXYGEN SUPPLY SYSTEM:

For the purpose of tests reported here compressed oxygen stored in the cylinder is used. The oxygen and the atmospheric air is mixed in the mixing chamber provided before entering to the intake manifold of the engine. A separate oxygen flow meter is located in the cylinder which is used to measure the intake oxygen content of the system. The amount of oxygen supplied from the cylinder varies from 0 LPM to 2 LPM.

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 higher output temperature which is expected to be produced.

5. EXPERIMENTATION PROCEDURE:

The Load Test was conducted on three different conditions namely,

- Without any additional O_2 supply (Base)
- With 1 LPM of O_2 supply
- With 2 LPM of O_2 supply

5.1 WITHOUT ANY ADDITIONAL O_2 SUPPLY (BASE):

OBSERVATIONS: The following observations were made by testing the engine without any additional O_2 supply,

S.NO	LOAD		SPEED (RPM)	Time taken for 5cc of fuel consumption. (seconds)
	KG	N		
1	0	0	1588	41
2	2	19.62	1574	34
3	4	39.24	1554	29
4	6	58.86	1548	23
5	8	78.48	1538	18

Table 2:

Observations without any additional O_2 supply

The following values are calculated without any additional O_2 supply,

S.NO	TFC	BP kW	HS kW	η_{bt} %	FP kW	IP kW	η_{mech} %	η_{IT} %	SFC Kg/kW.hr
1	0.364	0	4.24	0	2	2	0	47.1	0
2	0.439	0.824	5.12	16	2	2.82	29.07	55	0.53
3	0.515	1.627	6	27.1	2	3.62	44.7	60	0.316
4	0.649	2.431	7.5	32.4	2	4.43	54.8	59	0.266
5	0.83	3.221	9.68	33.2	2	5.22	61.6	53.9	0.257

Table 3: Calculated values without any additional O_2 supply

5.2 FOR 1 LPM OF O_2:

OBSERVATIONS: The following observations were made by testing the engine with 1 LPM of O_2 supply,

S.NO	Load		Speed (RPM)	Time taken for 5cc of fuel consumption. (seconds)
	KG	N		
1	0	0	1573	43
2	2	19.62	1560	37
3	4	39.24	1554	30
4	6	58.86	1548	26
5	8	78.48	1536	19

Table 4: Observations under 1 LPM of O_2 supply

FRICTION POWER: Using WILLAN'S LINE method Friction power can be calculated and it is Here, FP = 1.75kW

TABULATION: The following values are calculated with 1 LPM O_2 supply,

S.No	TFC	BP (Kw)	HS(Kw)	η_{bt} %	FP(kW)	IP(kW)	η_{mech-} %	η_{IT-} %	SFC (Kg/kW.hr)
1	0.347	0	4.04	0	1.75	1.75	0	43.3	0
2	0.403	0.816	4.7	17.3	1.75	2.56	31.8	54.4	0.493
3	0.498	1.627	5.81	28	1.75	3.37	48.2	58	0.306
4	0.574	2.43	6.69	36.3	1.75	4.18	58.1	62.4	0.236
5	0.786	3.216	9.17	35	1.75	4.96	64.8	54	0.244

Table 5: Calculated values under 1 LPM of O_2 supply

5.3 FOR 2 LPM OF O_2:

OBSERVATIONS: The FRICTION POWER: Using WILLAN'S LINE method Friction power can be calculated and is Here, FP = 1.5 kW

The following observations were made by testing the engine with 2 LPM of O_2 supply,

S.No	Load		Speed (RPM)	Time taken for 5cc of fuel consumption (seconds)
	KG	N		
1	0	0	1576	47
2	2	19.62	1560	40
3	4	39.24	1554	31
4	6	58.86	1550	29
5	8	78.48	1534	20

Table 6 Observations under 2 LPM of O_2 supply

S.NO	TFC Kg/hr	BP kW	HS kW	η_{bt} %	FP kW	IP kW	η_{mech} %	η_{IT} %	SFC Kg/kW.hr
1	0.317	0	3.68	0	1.5	1.5	0	40.7	0
2	0.373	0.816	4.31	18.7	1.5	2.31	35.3	53.1	0.456
3	0.481	1.627	5.61	29	1.5	3.12	52.1	55.6	0.295
4	0.515	2.434	6	39.5	1.5	3.93	61.9	65.5	0.211
5	0.747	3.212	8.715	36.8	1.5	4.71	68.1	54	0.232

TABULATION: The Table 7: Calculated values under 2 LPM of O_2 supply

6. RESULTS AND DISCUSSION:

After conducting the set of experiments the following results were arrived, 6.1. TFC:

The variation of total fuel consumption (TFC) at various loads of the base engine is compared with the modified engine at increased oxygen flow rates is shown in the Figure 7.1. It is observed that there is fall in the TFC at all loads when the oxygen flow rate is enhanced.

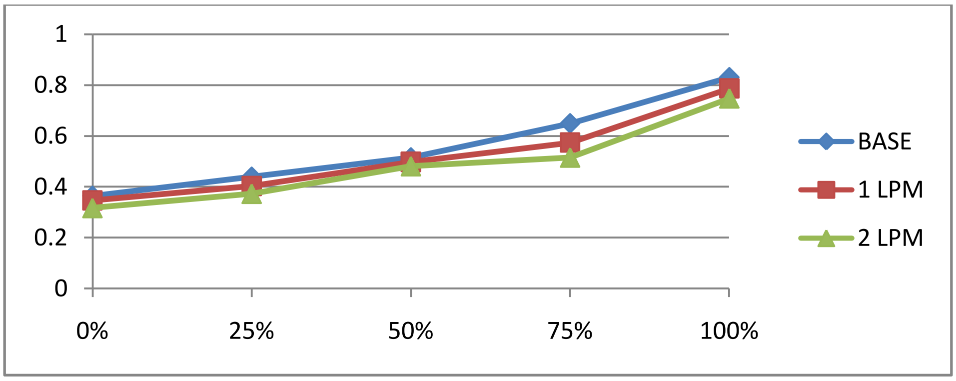


Figure 1: Load vs TFC

6.2. SFC:

The variation of specific fuel consumption (SFC) at various loads of the base engine is compared with the modified engine at increased oxygen flow rates is shown in the Figure 7.2. It is observed that there is fall in the SFC at all loads when the oxygen flow rate is enhanced.

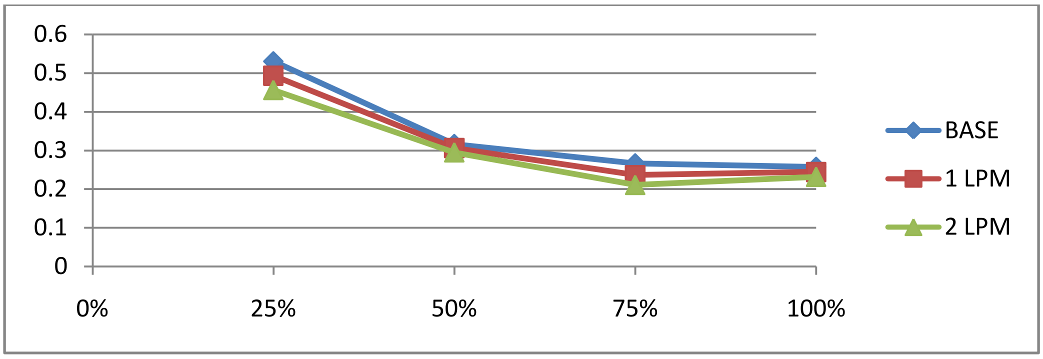


Figure 2: Load vs SFC

6.3. BRAKE THERMAL EFFICIENCY:

The variation in Brake thermal efficiency at various loads of the base engine is compared with the modified engine at increased oxygen flow rates is shown in the Figure 7.3. There is an improvement in the brake thermal efficiency at all loads when the oxygen flow rate increased. This improvement is may be due to better combustion with enhanced oxygen flow rate.

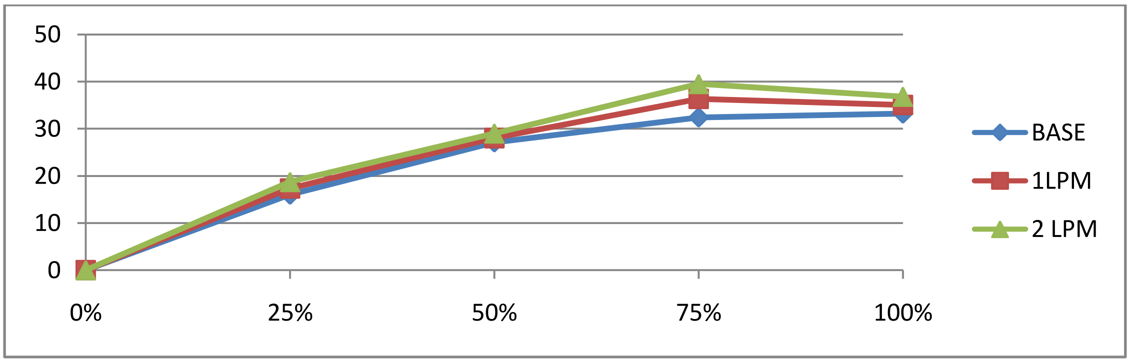


Fig 3: Load vs Brake thermal efficiency

6.4. MECHANICAL EFFICIENCY:

The variation in mechanical efficiency at various loads of the base engine is compared with the modified engine at increased oxygen flow rates is shown in the Figure 7.4. There is an improvement in the mechanical efficiency at all loads when the oxygen flow rate increased. This improvement is may be due to decreased friction power.

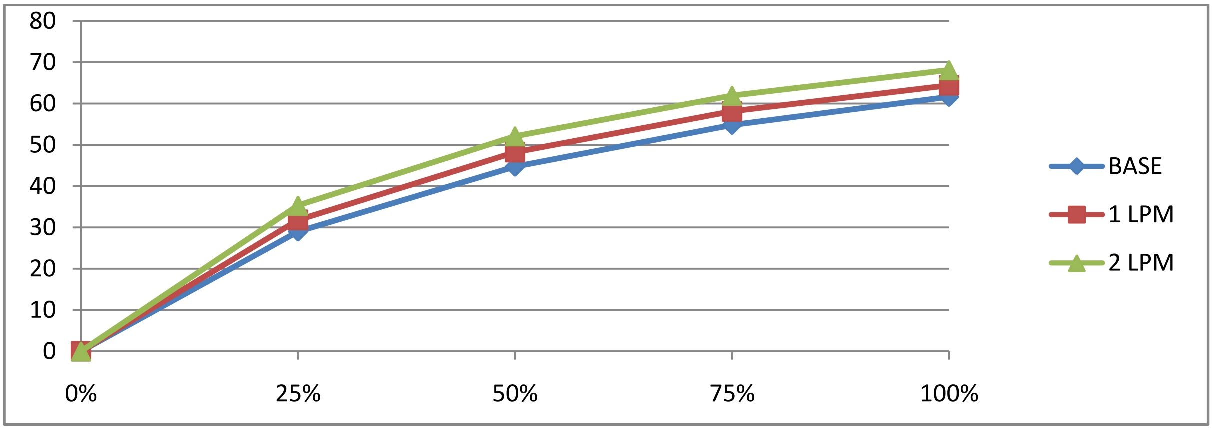


Figure 4: Load vs Mechanical efficiency

6.5. INDICATED THERMAL EFFICIENCY:

The variation in indicated thermal efficiency at various loads of the base engine is compared with the modified engine at increased oxygen flow rates is shown in the Figure 7.5. The indicated thermal efficiency decreases at all load levels but increased at 75% load level.

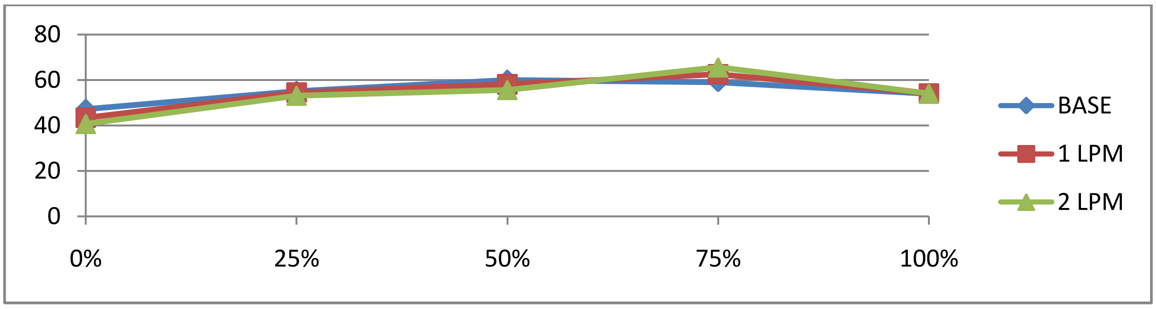


Fig 5: Load vs Indicated thermal efficiency

7. CONCLUSION:

The experiment conducted on single cylinder diesel engine under different load conditions and quantity of oxygen supply. The following observations are arrived, they are

- TFC decreased at all loads when the oxygen flow rate is enhanced. The fall in TFC is high at 75% load level.
- SFC is also decreased at all loads when the oxygen flow rate is enhanced. The fall in SFC is high at 25% condition.
- There is an improvement in the brake thermal efficiency at all loads when the oxygen flow rate increased. The improvement is high at 75% load level.
- Mechanical efficiency increases gradually at all loads when the oxygen flow rate increased.
- There is gradual decrease in friction power when oxygen flow rate increased.

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