International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE)
ISSN: 0976-1353 Volume 22 Issue 1 – MAY 2016.

PERFORMANCE ANALYSIS OF SINGLE CYLINDER FOUR STROKE DIESEL ENGINE WITH OXYGEN ENRICHMENT AND ALTERNATE FUEL (NEEM OIL)

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Abstract— **Now a days many of them are using diesel engines with minimum level efficiency and high emission due to the incomplete combustion in the cylinder. So that some of them are enriching the oxygen and adding alternative individually .But we are enriching the oxygen and adding alternate fuel at the same time. Oxygen enriched and addition of alternative fuel in combustion chamber is one of the attractive combustion technologies is to improve combustion in diesel engine In this we are using a single cylinder direct injection diesel engine is to study the impact of oxygen enrichment and addition of alternative fuel for performance parameters by increasing the oxygen concentration of intake air from 21 to 27% by volume and adding alternative fuels will Increase the Combustion Rate & Decrease the Emission.**

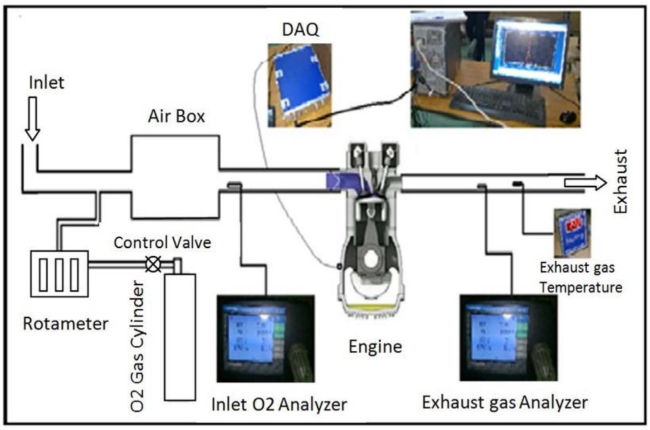
I. INTRODUCTION

Diesel engine manufacturers face a major challenges to meet the power requirement with high combustion efficiency. Moreover how to decrease fuel consumption has put focus on the automobile industry and forced 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 exciting and promising technologies in the hunt for new engine solutions for an increasingly eco-aware and resource-efficient world. The reason for the diesel engine's success lies in Rudolf Diesel's original idea: to create an engine with the maximum "thermodynamic efficiency rating" - something that is achieved when as much as possible of the fuel's energy is used to propel the vehicle instead of literally going up in smoke. What is special about the diesel engine is that it compresses both air and fuel under very high pressure. When the fuel in the cylinder ignites leads to the heat generated by the high degree of compression, this generates the power that sets the piston in motion. The first functioning diesel engine came in 1897 and it boasted an efficiency rating of 26 percent, way beyond the mere 12 percent efficiency of the contemporary steam engine. Today's modern trucks are powered by diesel engines with an efficiency rating of about 46 percent. A significant development, to say the least.

A number of experimental studies have demonstrated the benefits of applying OECT in diesel engines. 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 was compared with different load with different level of oxygen enrichment to evaluate the above mentioned combustion parameters. Other aspect of oxygen enrichment like engine performance, reduction in particulates, smoke and unburned HC are not included in this paper. Energy is the most fundamental requirement for human existence and activities. As an effective fuel, petroleum has been serving the world to meet its need of energy consumption. But the dependence of mankind entirely on the fossil fuels could cause a major deficit in future. The worldwide concern about the protection of environment and the safety of non-renewable natural resources, has given rise to alternate development of sources of energy as substitute for traditional fossil fuels.

The major part of all energy stimulated worldwide comes from fossil sources (petroleum, coal and natural gas). However, these sources are inadequate and will be exhausted. Thus, looking for alternative sources of new and renewable energy such as hydro, biomass, wind, solar, geothermal, hydrogen and nuclear is of fundamental importance. Alternative and renewable fuels are the possible solution for many of the current social problems and concerns, from air pollution and global warming to other environmental improvements and sustainability issues The main advantages of using biodiesel is that it is eco- friendly, can be used without modifying existing engines, and produces less harmful gas emissions such as carbon monoxide, hydrocarbon and sulfur di oxide. 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.

II. ENGINE MODIFICATION FOR OXYGEN ENRICHMENT



2.1 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 from1 Liters per Minute (LPM) to 4 L min^{-1}

2.2 Air flow measurement:

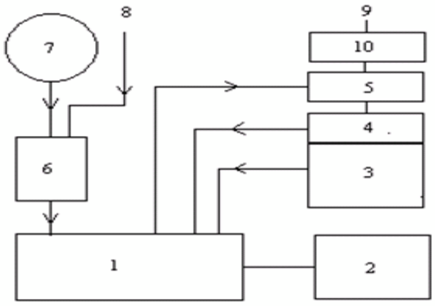
The air flow to the engine is routed through cubical air tank. The air tank fulfills the purpose of regulating the flow of air to the tank. The inlet of the air tank is provided with an orifice, the air flow rate is measured using the mass air flow sensor. A hot wire mass air flow sensor determines the mass of air flowing in to the engines air intake stream. This is achieved by heating a wire with an electric current that is suspended in the engines air stream. The wire electrical resistance increases with the wires temperature, which limits electrical current flowing through the circuit. The amount of current required to maintain the wire electrical resistance is directly proportional to the mass of air flowing past the wire.

2.3 Fuel delivery system:

The Fuel from the tank is connected to a solenoid valve. The outlet of the solenoid valve is connected to a glass burette and the same is connected to the engine through a manual ball valve. The fuel solenoid of the tank will remain open until the burette is filled to the high level sensor, during this time the fuel is flowing to the engine directly from fuel tank and also fills the burette. Once after sensing the top level, the fuel solenoid closes fuel tank outlet line, now the fuel in the burette gets discharge to the engine. When the fuel level reaches the high level optical slot sensor, the sequence running in the computer records the time of this event. Likewise when the fuel crosses the low level optical slot sensor, the sequence running in the computer records the time of this event. And immediately the fuel solenoid opens filling up the burette and the cycle is repeated. Here the injection is direct with multi whole nozzle.

III. MATERIALS AND METHODS

The test engine was a single cylinder water cooled kirloskar diesel engine with computerized data acquisition system. The schematic diagram of the experimental setup is shown in Fig.



(1) Engine (2) Eddy current dynamometer (3) Computer with data acquition system (4) Fuel tank (5) Calorimeter (6) Mixing chamber (7) Oxygen cylinder with flow meter (8) Atmospheric air (9) Exhaust gas to the atmosphere (10) Multi gas analyzer

Fig 3.1 Systematic diagram

One of the methods to reduce the emissions in a diesel engine is by oxygen introduction into the combustion chamber which can be done by supplying the oxygen into the inlet manifold during suction stroke. Oxygen affects different parameters such as brake thermal efficiency, fuel consumption, NOx and smoke at different load conditions. Load test was conducted for various concentrations of oxygen (21 to 27 percent) in terms of 2%. It is found that oxygen enrichment leads to better combustion which in turn results in less fuel consumption and an increase in brake thermal efficiency.

It was found that about 25% oxygen enrichment in the inlet air results in the optimum performance and emission characteristics. The result shows that varying oxygen enrichment in the inlet air increases brake thermal efficiency and subsequently decreases brake specific fuel consumption. It was also found that an oxide of nitrogen (NOx) increases exponentially whereas smoke intensity falls below the normal level. In most combustion processes, various kinds of hydrocarbon fuels are used. Regarding fossil fuel combustion, due to increasing concerns over environmental pollutants such as soot particulates, carbon monoxide, unburned hydrocarbon, nitrogen oxides and sulfur dioxide, development of emission reduction methods has become an imminent issue for practical application to numerous combustion devices.

Reduction of engine emissions is a major research aspect in engine development with the increasing concern on environmental protection and the stringent exhaust gas regulations. It is difficult to reduce all emissions simultaneously in normal Diesel engines. Many in-cylinder and exhaust post-treatment techniques are currently being investigated to reduce NOx and smoke emissions to the acceptable levels. Altering the composition of air provides automotive engineers to solve difficult environmental problems. When the test engine reached stable condition and preparations and settings for the measurements were finished the experiments started.

3.1 Rota meter

Rota meter is a device that measures the flow rate of fluid or air in a closed tube. It belongs to a class of meters called variable area meters, which measure flow rate by allowing the cross-sectional area the fluid travels through, to vary, causing a measurable effect. Once after sensing the top level, the fuel solenoid closes fuel tank outlet line, now the fuel in the burette gets discharge to the engine.

When the fuel level reaches the high level optical slot sensor, the sequence running in the computer records the time of this event. Likewise when the fuel crosses the low level optical slot sensor, the sequence running in the computer records the time of this event. And immediately the fuel solenoid opens filling up the burette and the cycle is repeated. Here the injection is direct with multi hole nozzle.

3.2 Oxygenated Fuel Additive

Oxygenated fuel is nothing more than fuel that has a chemical compound containing oxygen. It helps fuel to burn more efficiently and reduce some types of atmospheric pollution. It can also reduce deadly carbon monoxide emissions and smog formation. Oxygenated fuel works by allowing the fuel in vehicles to burn more completely. Because more of the fuel is burning, there are fewer harmful chemicals released into the atmosphere. In addition to being cleaner burning, oxygenated fuel also helps cut down on the amount of non- renewable fossil fuels consumed. Various additives used for oxygen enrichment of fuel are as below.

3.3 Requirements of Good Oxygenate Properties

Oxygenates that are to be blended with diesel fuel must have fuel properties appropriate for motor fuel.

The oxygenate must be miscible with various diesel fuels over the range of environmental temperature seen in vehicle operation.

3.4 Types Of Oxygenate Fuel Additives

Dimethoxylene (DME) is clear, colorless, aprotic, and liquid ether that is used as a solvent. DME is miscible with water and is often used as a higher boiling alternative to diethyl ether.

2-Ethylhexyl Acrylate is water white liquid with a characteristic odor. It is a stable product, with only negligible solubility in water. It is readily polymerized and displays a range of properties dependent upon the selection of the monomer and reaction conditions. 2-ethylhexyl acrylate is used in the production of homo- polymers. It is also used in the production of co-polymers, for example acrylic acid and its salts, esters, amides, methacrylates, acrylonitrile, maleates, vinyl acetate, vinyl chloride, vinylidene chloride, styrene, butadiene and unsaturated polyesters. 2-ethylhexyl acrylate is also used in pressure sensitive adhesives.

Dimethyl Carbonate, often abbreviated DMC, is a flammable clear liquid boiling at 90 °C. It is a carbonate ester which has recently found use as a methylating reagent. It was also classified as an exempt compound under the definition of volatile organic compounds by the U.S. EPA in 2009. Its main benefit over other methylating reagents such as iodomethane and dimethyl sulfate is its much lower toxicity and its biodegradability. Also, it is now prepared from catalytic oxidative carboxylation of methanol with carbon monoxide and oxygen, instead of from phosgene. This allows dimethyl carbonate to be considered a green reagent.

It was found that soot concentration is maximum when pure diesel was burned, followed by emulsified fuels and the lease concentration was obtained when bio-fuel was burned. Further, methanol has the most significant effect on the reduction of soot once added to each fuel, while acetone has the lease effect on soot reduction. The results gave good indication of the effect for oxygenated additives in reduction the soot formation.

IV. ALTERNATIVE FUEL

A fuel other than petrol or diesel for powering motor vehicles, such as natural gas, methanol, or electricity. Alternative fuels, known as non-conventional or advanced fuels, are any materials or substances that can be used as fuels, other than conventional fuels like; fossil fuels (petroleum (oil), coal, and natural gas), as well as nuclear materials such as uranium and thorium, as well as artificial radioisotope fuels that are made in nuclear reactors.Some well-known alternative fuels include biodiesel, bio alcohol (methanol, ethanol, butanol), chemically stored electricity (batteries and fuel cells), hydrogen, non-fossil methane, non-fossil natural gas, vegetable oil, propane and other biomass sources.

4.1Neem oil

Neem oil is proved to contain methyl ester which is considered to be the base of a bio diesel. This bio diesel contains alkyl esters of the fatty acids which is the product of the tranesterfication process of the neem oil. Extraction of this diesel is complicated but its results are more efficient like low carbon emission, increases the engine performance, brake specific fuel is saved and reduces the smoke density.

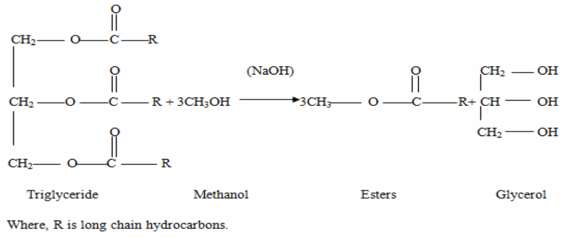
India is expected to be one of the largest bio-diesel producers as the resources of production of such fuel like neem, jatropa and pongamia plantation is very high in that region. Africans will also be the leading companion along with India in near future as they extract bio-diesel from sugarcane. Market for Neem oil suppliers and products were also been boosted up due to its advantages in many field. In the new era of Bio-fuel, Neem Oil even though has its own identity as a medicinal plant, creates a new spot as a bio diesel. Thus this nature's gift once again lends its help in reviving us from the darkness of the world's destruction.

Average composition of neem oil fatty acids		
Common Name	**Acid Name**	**Composition range**
Omega-6	Linoleic acid	6-16%
Omega-9	Oleic acid	25-54%
Palmitic acid	Hexadecanoic acid	16-33%
Stearic acid	Octadecanoic acid	9-24%
Omega-3	Alpha-linolenic acid	?%
Palmitoleic acid	9-Hexadecenoic acid	?%

4.2Biodiesel Production method

4.2.1Total process followed two stages

Firstly, to reach the equilibrium conditions at temperature 55-65°C. Secondly, for glycerin separation the product mixture was stimulated continuously and then allowed to settle under gravity in a separating funnel .Two distinct layers form after gravity settling for 24h. The upper layer was of ester and lower layer was of glycerol. The lower layer was separated out. The separated ester contains 3% to 6% methanol and usually some soap. If the soap level is low enough (300 to 500 ppm), the methanol can be removed by vaporization and this methanol will usually be dry enough to directly recycle back to the reaction. After the removal of methanol, the biodiesel needs to be washed to remove residual free glycerin, methanol, soap, and catalyst. Biodiesel was mixed with some warm water (around 10 % volume of ester) to remove the catalyst present in ester and allowed to settle under gravity for another 24h.



Although the gray water from later washes can be used as the supply water for the earlier wash steps, the total amount of water will typically be one or two times the volume flow rate of the biodiesel. I used 10% of water of total volume of biodiesel and heated above 100°C. The residual methanol and water both were vaporized. Weaker organic acid, such as citric acid, will neutralize the catalyst and produce a soluble salt.

Stronger inorganic acid such as hydrochloric, sulfuric, or phosphoric, can be used to split the soap and this reduces the water requirement to 5% to 10 % of the biodiesel because the salts are easier to remove than the soap. Although I applied water washing technique for separation of residual methyl esters but instead of using water washing, solid absorbents such as magnesium silicate can be used for this purpose. The fine powder of absorbents absorbs the contaminants such as soap, catalyst, and free glycerol.

The overall processing of biodiesel from Neem oil consists of the collection of oil from Neem seeds first. Combined reaction of alcohol, catalyst &oil takes place. Catalyst works here as the unchangeable compound which runs the reaction speedy well. The schematic diagram of the production of biodiesel from oil is given bellow

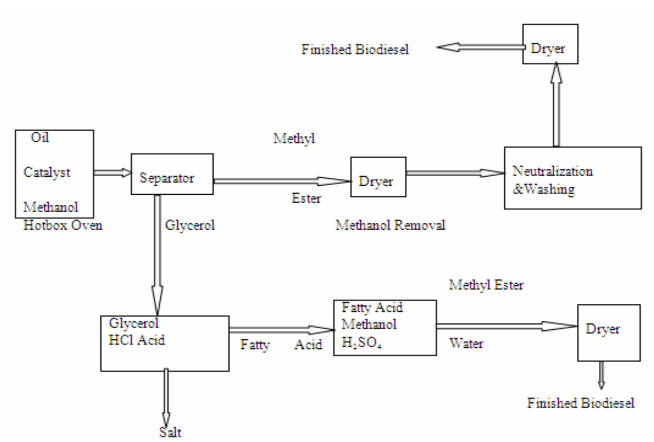


Fig.4.1 Schematic of biodiesel processing

When the separation of esters and glycerol occurs, glycerol contains soaps, catalyst, methanol & other impurities. So for the improvement of this situation, purity of the glycerol is needed. To neutralize the catalyst and split the soap strong hydrochloric acid (HCl) was added to the glycerin.

In the glycerin, the free fatty acids are not soluble; so it can be easily separated using a centrifuge. There is a special concern that high free fatty acid (FFA) during biodiesel production may cause obstruction to the separation of methyl esters and glycerin.

The acid based catalization slows the transesterification reaction. The two-step approach of acid-catalyzed esterification followed by base-catalyzed transesterification gave a complete reaction at moderate temperature (50 to 61°C). The biodiesel we need was processed finally by drying the found methyl ester

Fig 4.2 Hotbox Oven Chamber

Fig.4.3 Different layers after reaction

The cost of the biodiesel production can be minimized as possible to recover the used methanol. Recycling of methanol again and again in mass production and commercial use the cost must be come to the lowest amount. Also the by-product such as glycerin and soap play an important role to minimize the cost

Fuel/properties	Kinematic viscosity 40°C(cSt)	Flash point (°C)	Density (kg/m^3)	Calorific value (kJ/kg)
Diesel	3.02	52	806	43796
B10	4.5	65	837	44840

Table 4.1 Properties of Diesel and Neem oils

V. FORMULAE USED

1. Break power (BP) $=2NwR_2/60$

2. Total fuel consumption (TFC) =

$$\frac{\text{Measured fuel(5cc)*sp gravity*3600}}{\text{TimetakeninSeconds*1000}}$$

3. Specific fuel consumption (SFC) =TFC/BP

4. Friction power from the graph in between TFC and BP by WILLIAN'S LINE

METHOD: - In this method total fuel consumption (TFC) vs. Brake power at constant speed is plotted and graph is extrapolated back to zero fuel consumption the point where the graph cuts the brake power axis is an indication of the friction power of the engine at that speed. This negative work represents the combined loss due to mechanical friction, pumping and blow by. This test is applicable to compression ignition engines.

5. Indicated power (IP) = BP + FP
Where BP = brake power FP = friction power
6. Mechanical efficiency (ŋ mech) = BP/IP
7. Indicated thermal efficiency (ŋithe) = IP/ (TFC * CV)

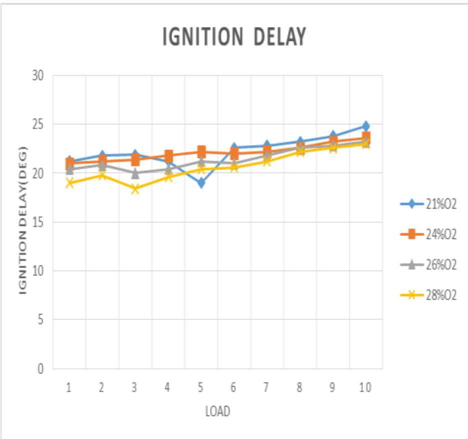
VI. RESULT AND DISCUSSION

6.1Ignition delay

The delay period in the CI engine exerts a very great influence on both engine design and performance. This is because of its effect on both the combustion rate and knocking and also its influences on engine start ability. Oxygen enriched air have revealed large decrease of ignition delay stated by Rakopoulossss National Technical university of atherns. From the literature it was clear that reduction in ignition delay can be achieved with oxygen enrichment. Effect of oxygen enrichment does not influences physical delay but it has greater influences on chemical delay.

	Ignition delay (deg)			
Load	21%O2	24%O2	26%O2	28%O2
1	21.2	21	20.4	19
2	21.8	21.2	20.8	19.8
3	21.9	21.4	20	18.4
4	21.2	21.8	20.4	19.6
5	19	22.2	21.2	20.4
6	22.6	22	21	20.6
7	22.8	22.2	21.8	21.2
8	23.2	22.6	22.6	22.2
9	23.8	23.2	22.8	22.6
10	24.8	23.6	23.2	23

Table 6.1 Load v_s Ignition delay



From the tabulated results it was clear that oxygen enriched combustion plays a considerable role in decreasing the ignition delay period. An average of 3 to 4% decrease in delay period for the enrichment of 21%. Oxygen. In similar way an average of 6% decrease in delay period can be obtained for the enrichment of 28% Oxygen

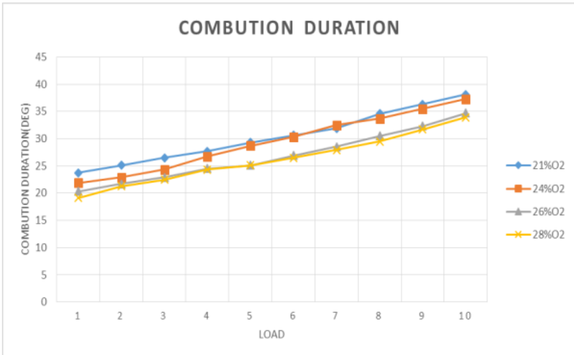
6.2 Combustion duration

Fuel oxygen enrichment results in an increase of brake specific consumption and a reduction of combustion duration

Combustion duration for varies oxygen enrichment level was presented in the following table. From the tabulated results an average decrease of 8 % in combustion duration (deg) can be arrived for the enrichment level of 24% of oxygen. Similarly a maximum of 23% of reduction in the combustion duration can be obtained for the enrichment level of 28% of oxygen

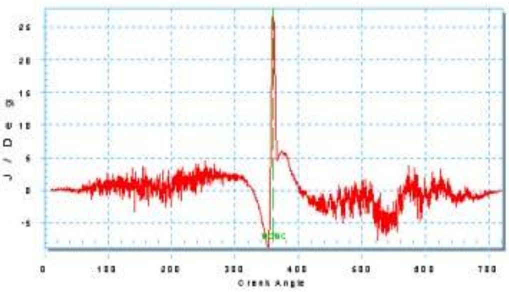
	Combustion duration (deg)			
Load	21%O2	24%O2	26%O2	28%O2
1	23.7	21.9	20.3	19.1
2	25.1	22.9	21.7	21.3
3	26.5	24.3	22.9	22.5
4	27.7	26.7	24.5	24.3
5	29.3	28.7	25.1	25.1
6	30.6	30.3	26.9	26.5
7	31.9	32.5	28.5	27.9
8	34.6	33.7	30.5	29.5
9	36.3	35.5	32.3	31.7
10	38.1	37.3	34.7	33.9

Table 6.2 Load v_s Combustion duration



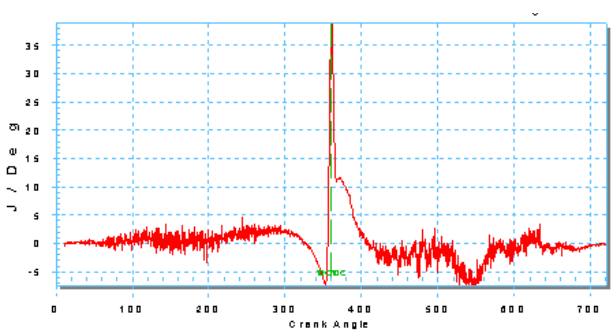
6.3 Heat Release

In a diesel engine, combustion occurs via a flame. Hence at any point in time, only a fraction of the total fuel is burning. This results in low peak pressures and low energy release rates. In oxygen enriched combustion the fuel/air mixture ignites and burns in a fast rate resulting in high peak pressures and high energy release rates. Rates of heat release from fuel combustion are closely related to peak combustion temperature hence high combustion temperature leads to maximum rate of heat release. In this study heat release rate can be taken directly from the combustion page. Maximum rate of 1500 kW or the enrichment level of 21% and the maximum of 2300 kW for the enrichment of 35% of oxygen was obtained by R.R. Sekar., 1990 fall technical conference



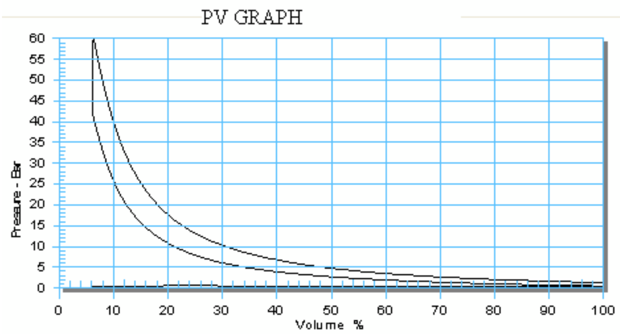
From the above graph it is clear that maximum rate of heat release of 27.8 J/Deg was obtained from the experiment conducted without oxygen enrichment for the oxygen level of 21%.

At the maximum of 40.2 J/Deg was obtained from the test for the enrichment of 28% of oxygen enrichment shown in the following graph. An average of 50% increase in the heat release can be obtained from the oxygen enrichment technology for the enrichment of 28% of oxygen. From this it is very clear that oxygen enriched combustion technology plays an important role in increasing the heat release rate.

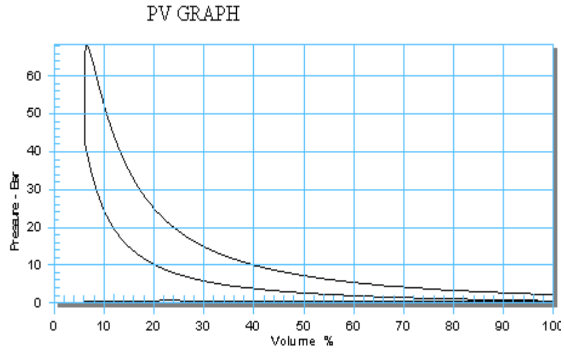


6.4 Cylinder pressure

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.



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 .A pressure of 60 bar can be obtained from the test results for the engine with above mentioned specifications with the oxygen level of 21%.

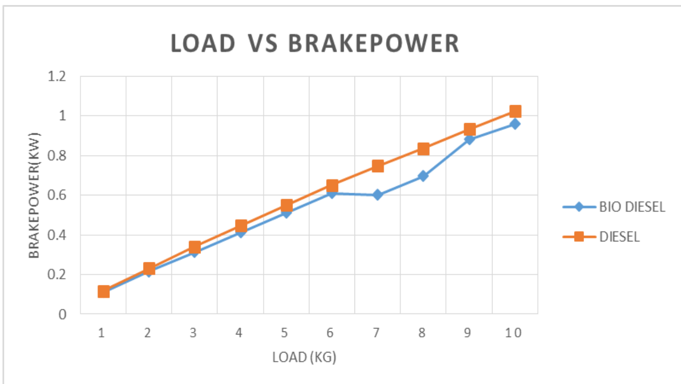


A maximum pressure of 68 bar can be obtained with oxygen enrichment level of 28 % for the same load. i.e. An average of 12% increase in peak pressure can be obtained.

6.5 BRAKEPOWER (BP)

	BRAKEPOWER(BP)	
LOAD	BIO DIESEL	DIESEL
1	0.1099	0.1167
2	0.216	0.232
3	0.314	0.342
4	0.413	0.446
5	0.512	0.55
6	0.6094	0.652
7	0.602	0.748
8	0.696	0.837
9	0.882	0.933
10	0.96	1.023

Table 6.3 Load Vs Brakepower

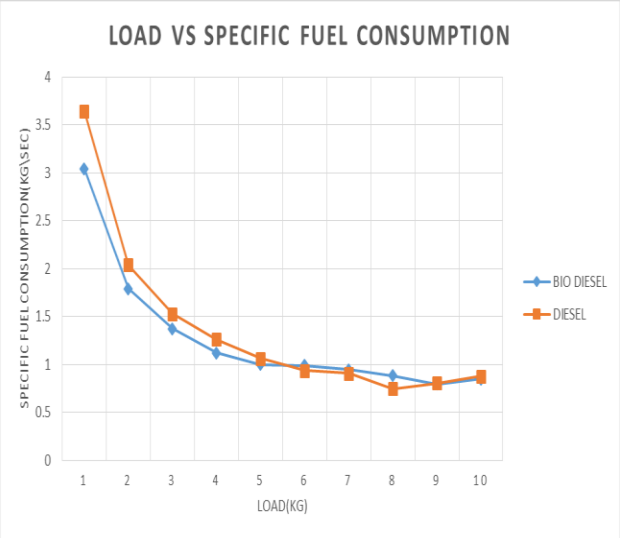


6.6 SPECIFIC FUEL CONSUMPTION

	LOAD Vs SPECIFIC FUEL CONSUMPTION	
LOAD	BIO DIESEL	DIESEL
1	3.044	3.647
2	1.789	2.038
3	1.371	1.53
4	1.122	1.261
5	0.998	1.06
6	0.989	0.933

7	0.944	0.905
8	0.884	0.745
9	0.795	0.805
10	0.85	0.876

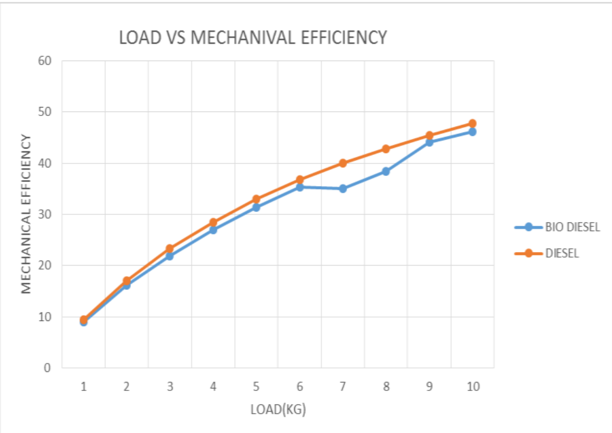
Table 6.4 Load Vs Specific Fuel Consumption



6.7 MECHANICAL EFFICIENCY

	LOAD Vs MECHANICAL EFFICIENCY	
LOAD	BIO DIESEL	DIESEL
1	8.94	9.45
2	16.18	17.05
3	21.91	23.41
4	26.97	28.5
5	31.39	32.95
6	35.26	36.8
7	34.98	40.06
8	38.35	42.79
9	44.08	45.47
10	46.18	47.76

Table 6.5 Load Vs Mechanical Efficiency



VII. CONCLUSION

The results showed that at all engine speeds, the dominant frequency was the piston stroke frequency of the engine and the frequency of vibration increased by raising the engine speed. The experiments indicated that the magnitude of vibration of the power tiller engine depends on the axis of measurement, engine speed and the fuel blends. Vibration acceleration was significantly affected by engine speeds and the increase in forward speed due to the increase in vibration acceleration rms. Results of experiments revealed that the vibration acceleration was significantly affected by the axis of measurement. The vibration acceleration value in vertical axis was more than that in the other two axes and in the longitudinal axis was more than that in lateral axis. Fuel blends significantly influenced the vibration.

REFERENCE

[1] Rajkumar, K. and P. Govindarajan, 2010. Experimental investigation of oxygen enriched air intake on combustion parameters of a single cylinder diesel engine. Int. J. Eng. Sci. Technol., 2: 3621-3627.

[2] Momani, W., 2009. The effects of excess oxygen to mixture on the gasses emissions Of a gasoline engine. Am. J. Applied Sci., 6: 1122-1125.

[3] DOI:10.3844/ajassp.2009.1122.1125

[4] Najafi, G., B. Ghobadian, T.F. Yusaf and H. Rahimi, 2007. Combustion analysis of a CI engine performance using waste cooking Biodiesel fuel with an artificial neural network aid. Am. J. Applied Sci., 4: 759-767.DOI: 10.3844/ajassp.2007.759.767

[5] Rakopoulos, C.D., D.T. Hountalas, T.C. Zannis and Y.A. Levendis, 2004. Operational and environmental evaluation of diesel engines burning oxygen-enriched intake air or oxygen-enriched

[6] Fuels: A Review. SAE International. DOI: 10.4271/2004-01-2924.

[7] Shraddha R Jogdhanka, S D Rahul Bharadwaj –Alternative fuels and performance of CI-engine running on neem oil and biodiesel blends‖. International Journals of Environment Science, Volume 4 No.2 (2013).

[8] Love Kush Prasad and Dr. Alka Agrawal, –Experimental Investigation of Performance of Diesel Engine Working On Diesel and Neem Oil Blends,‖ IOSR Journal of Mechanical and Civil Engineering (IOSRJMCE) ISSN: 2278-1684 Volume 1, Issue 4 (July-August 2012), PP 48-51

[9] A.V.Kulkarni and S.D.Bhopale, –Performance Analysis and Investigation of Emission of C.I. Engine Using Neem Oil as Blending‖ International Journal of Innovative Research in Science, Engineering and Technology. An ISO 3297: 2007 Certified Organization, Volume 3, Special Issue 4, April 2014.

[10] Rakopoulos, C. D., Antonopoulos, K. A., Rakopoulos, D. C. and Hountalas,

[11] D. T., "Multi-zone modeling of combustion and emissions formation in diesel engine operating on ethanol diesel fuel blends", energy conversion and management, Vol. 49, No. 4, 2008, pp.625–643.

[12] Fleisch, T. H., Basu, A., Gradassi, M. J. and Masin,

[13] J.G., "Dimethyl ether: a fuel for the 21st century", studies in surface science and catalysis, Vol. 107, 1997, pp. 117-125.

[14] Poola, R. B., et al., "Utilizing intake air oxygen-

[15] enrichment technology to reduce cold-phase emissions", SAE paper,

[16] No. 952420.

[17] Donahue, R. J. and Foster, D. E., "Effect of oxygen

[18] enhancement on the emission from DI diesel via manipulation of fuel and combustion chamber gas composition", SAE paper, No. 2001-01-0512.