Experimental emission control investigation on Kirloskar Research Engine using Combined Effect of 2-Ethoxy-Ethanol and 2-Methoxy-Ethanol as oxygenates at various proportion with diesel Fuel

Vasanthaseelan S[1*], Gowthamrajan S[2], Rajeshkumar G[3]
[1]Department of Automobile Engineering, S.N.S College of Technology, Coimbatore, Tamil Nadu, India,
[2]Department of Automobile Engineering, Kalasalingam University, Sankarankovil, Srivilliputhur, Tamil Nadu
[3]Department of Mechanical Engineering, Theni Kammavar Sangam College of Technology, Theni, Tamil Nadu
***Corresponding author: E-Mail: vasanthaseelans@gmail.com**

ABSTRACT

In recent days, increase in usage of fossil fuels leads to rapid increase in the amount of emission from the engine which propels the researchers to develop an alternative to fossil fuels. Biodiesel is considered as potential alternative to regular fossil fuels to reduce emission in compromise with in the engine performance. To overcome this conflict in this research, we have studied the effect of using oxygenated fuel such as 2-Ethoxy Ethanol and 2-Methoxy Methanol with diesel as additive and the emission parameters of the engine such as Carbon monoxide, smoke, Hydrocarbons, Carbon Monoxide and Oxides of Nitrogen emissions are studied in detail. The results shows the reduction in smoke by 50% at lower speeds a further continues to reduce till 28% at higher RPMs. Similarly HC emission also showed reduced numbers from 44.22 ppm to 23.61 ppm at low speeds and 20.87 ppm to 7.35 ppm at high speeds. There was similar trend found in CO and CO_2 emission. The oxygen present in the additive aim to increase in the NOx emission from 32 ppm to 36 ppm in low speeds and 15 ppm to 16 ppm at high speeds.

KEY WORDS: oxygenated fuel, 2-Ethoxy Ethanol, 2-Methoxy Methanol, HC emission, NOx emission, Smoke reduction.

1. INTRODUCTION

The current scenario of fossil fuel consumption and their irreversible effect on natural environment in large scale; potentially urged researchers to overcome these problems. Contemporarily for reducing the pollution caused through internal combustion engine, bio-diesels derived from various species of animals, plants, microbes and few oxygenates were used as both fuel extender along with the conventional fuel or to be used as complete replacement with existing one. Incorporating biodiesels in existing engine model results in collective problem in major thrust areas such as comparatively low engine power than rated and high brake specific fuel consumption. Bio-diesels derived always possess low calorific value, higher density and viscosity. Use-age of biodiesels for prolonged period also constrained due to their fluctuating mass availability. Alternatively oxygenating the existing fossil fuel using derivatives of ethanol tends to show better emission results and enhanced performance results. Most commonly employed derivative supplements for fossil fuel are as ethanol, n-butanol and ethers. Nominal constrictions for the supplements is found to be high miscibility at wide proportions of fuel in any temperature, ability to improvise the Cetane index of the fuel with enhanced combustion properties. Additionally they must be low volatile and exhibit adequate water tolerance.

Elina (2015), in his research work impact of oxygenated additives to palm and jatropha biodiesel blends in the context of performance and emissions characteristics of a light duty diesel engine, explained the blending of ethanol derivatives with palm and jatropha biodiesel. Resulting blends were subjected to engine testing and emission parameters were measured with different derivative blends, simultaneously brake power and brake thermal efficiency also calculated. Results were found to be decreased peak pressure, better pre-mixed combustion. Brake power optimization is reached at J20 and P20 with same continuous steady state performance. On discussing with emission parameters smoke density tends to decrease irrespective of the derivative whereas ethanol doesn't have any significant effect of NO_x and CO emission. Finally he concluded n-butanol and diethyl ether has comparatively better improvement in terms of both performance and emission effectively.

Intenan (2014), in his experimental investigation on emission and performance improvement analysis of biodiesel-diesel blends with additives compared at various proportions of palm biodiesel, diesel and additives such as DP20, D80P15E5, D80P15B5 and D80P15DE5. Results shows the comparably improved results with respect to brake thermal efficiency, power, brake specific fuel consumption and emission parameters such as HC, CO, NO with respect to standard results. n-butanol shows optimal performance and emission characteristics. Nadir (2014), in their paper the influence of various oxygenated functional groups in carbonyl and ether compounds on compression ignition and exhaust gas emissions researched the chemistry behind using ethanol and carboxylic groups at various ratio for mixing with diesel as fuel extender and oxygenator. Employing carbonyl group results obtained collectively gives the improved emission control over other oxygenates. Parameters such as ignition delay, inline cylinder temperature, NO_x emission, particulate emission. They also conducted carboxylic group with double bond in functional improvise the ignition delay. Thus shows significant effect on combustion and emission parameters. Finally he concluded the effect of various oxygenate group and the carbon, oxygen bonding resonant on the emission.

2. MATERIALS AND METHODS

HHO Gas kit – Construction: HHO gas kit basically made of pair of stainless steel electrodes. It was connected to 32AH battery power source to achieve better and continuous power supply for electrolysis of water + KOH (37% to the volume of water) inside the container. Gas obtained as a result of electrolysis is by-passed to the engine air filter chamber through flexible tube. Whole kit is completely leak proof; silicon sealant is used to seal the gas kit. Plastic container, stainless steel electrode, silicon sealant, flexible tube and KOH were procured from proxor scientific pvt. ltd, Chennai. Power supply for electrolysis was by-passed from battery used for starting engine. In this experimental research Kirloskar engine of 5HP rated power of 553 cubic capacity was employed. Volume of electrolyte (water + KOH) taken for process depends on engine cubic capacity. Here electrolyte taken is 2.5 times the cubic capacity of engine i.e. 1400 cc (ml) of water and 37% of KOH to volume of water is dissolved i.e. 518 gms of KOH. These Specific amounts tends to produce continuous HHO gas to the engine without any smudge formation.

Oxygenate Fuel Properties: Initially selection of oxygenates for emulsion with diesel must satisfy the following criteria's such as presence of double bond near the functional group of the oxygenate, thus it makes the efficient emulsion and optimized combustion delay. Here two oxygenates subjected for experimentations were 2-Ethoxy ethanol and 2-Methoxy ethanol. They were selected in such way that the presence of double bond nearer to the functional group and their ability to emulsify with the diesel fuel at wide range of v/v ratio. Here oxygenate fuel contains 20% of additives and 80% of diesel. In the part of oxygenate taken for mixing, both oxygenates were equally taken in the ratio of 1:1. Initially 800ml of diesel was mixed with 200ml of additives (1:1 ratio of 2-Ethoxy ethanol and 2-Methoxy ethanol) and subjected for 8 hours of observation, resulting fuel obtained was found to be single layer, clear fuel with highly oxygenated.

Emission Characterization: AVL 444N- Di gas analyzer was employed to measure the emissions with and without oxygenates in the fuel. Table 1 shows the specification of the gas analyzer.

Table.1. Specification of flue gas analyzer used for testing emission

Measured quality	Measuring range	Resolution	Accuracy
CO	0 - 15% volume	0.01% Volume	0-10% ± 0.02%abs ±3% rel 10.01%- 15% ±5% rel
CO_2	0 - 20% Volume	0.01% Volume	0-16% ± 0.3%abs ±3% rel 16.01%- 20% ±5% rel
HC	0 – 30,000ppm Volume	≤ 2000;1ppm ≥ 2000;10ppm Volume	0-4000ppm ±8ppm 3%rel 4000-10000ppm 5%rel 10001-30000ppm 10%rel
O_2	0 - 25% Volume	0.01% Volume	±0.02% abs 1%rel
NO	0 - 5000 ppm Volume	1ppm Volume	±5ppm 1%rel
Engine speed	400 – 6000min $^{-1}$	1min^{-1}	±1% of indicated value
Oil temperature	0 - 125ºC	1ºC	±4ºC
Lambda	0 - 9.9999	0.001	Calculation of CO_2, CO, HC, NO

3. RESULTS AND DISCUSSION

Emission characteristics of oxygenated diesel fuel was investigated with respect to varying engine speed and table.2 shows the results of emission. The graphs have been plotted with respective emissions and engine speed for various trials and discussed below.

Table.2. Emission results for varying rpm condition

Trials	Condition	RPM	Smoke Density (N %)	HC (ppm)	CO (%)	CO_2 (%)	NO_X (ppm)
1	Before	500	12.22	44.21	0.128	73	32
	After		6.44	23.61	0.122	22	36
2	Before		12.01	40.90	0.084	65	29
	After		4.24	19.56	0.054	20	32
1	Before	1000	10.91	38.75	0.092	63	28
	After		4.22	19.12	0.082	18	31
2	Before		9.16	22.52	0.058	53	25
	After		2.62	13.57	0.028	16	28
1	Before	1500	9.22	34.31	0.062	46	21
	After		3.82	9.81	0.030	12	23
2	Before		7.26	20.87	0.041	42	15
	After		2.02	7.35	0.032	8	16

Smoke Emission: Smoke density is determined by the presence of quantity of soot particle in particulate matter. These soot particles were found to be adsorbed on the surface of the particles. It was found that intake air deficiency during combustion forms as the major attribute for high smoke density, additionally decreased air-fuel ratio and insufficient thermal cracking of carbon chain in fuel also plays key role in smoke density. The results shows that due to rapid combustion at higher engine speed, gradual decrease in smoke density observed. From the figure.1 it is clearly depicted that very low smoke density is observed between lower and higher rpm before the addition of oxygenates.

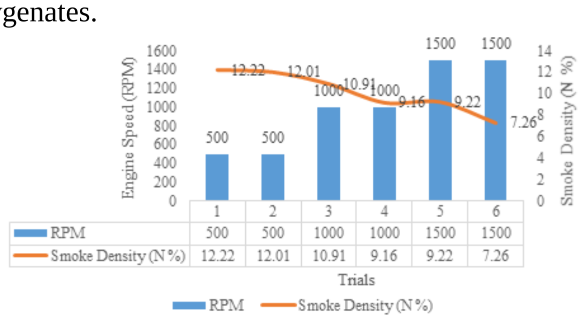

Figure.1. Smoke Density variation for various rpm before implementation

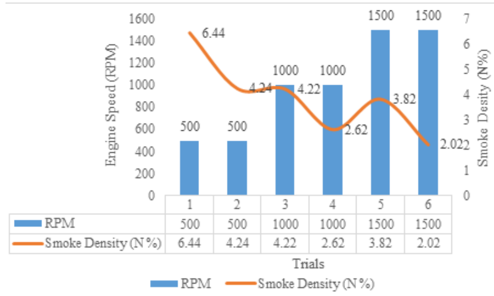

Figure.2. Smoke Density variation for various rpm after implementation

Effect of adding oxygenates results in clean and complete combustion as a result figure.2 shows the drastic change in smoke density with resulting very less soot particle emission, this happened due to complete oxidation of soot particle inside the combustion chamber.

Oxides of Nitrogen Emission: In the exhaust emission, nitric oxide and nitrogen dioxide were considered as most hectic-some of the Compression Ignition Engine Emissions. Most probably NO_x emission is mainly dependent on combustion chamber wall temperature, varying oxygen proportion and delay time (physical and chemical) during combustion process. From Figure.3 it shows NO_x emissions were lower at initial RPM and it gradually increases with increasing RPM due to sustained increase in residence time and other co-factors.

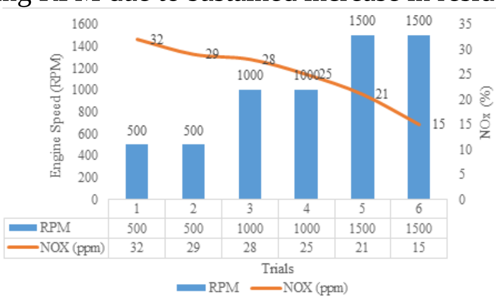

Figure.3. Nox Emission for various rpm before implementation

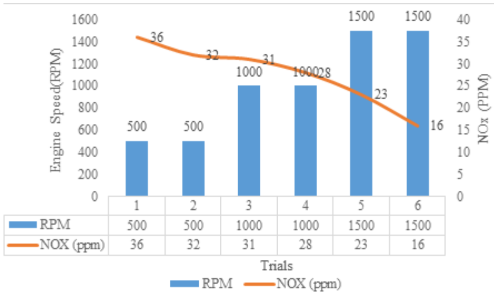

Figure.4. Nox Emission for various rpm after implementation

Figure.4 represents increased NO_x emission than the normal diesel fuel, this happens due to mixing of ethanol derivatives as oxygenates with fossil fuels. This explains that addition of ethanol with fossil fuel contemporarily results in enhanced combustion process due to perfect mixing, it also increases the effect of combustion chamber wall temperatures which significantly determines NO_x emission. Also that increased delay period due to poor fuel formulation and low cetane number characterization.

Oxides of Carbon Emission: As a result of incomplete combustion, due to lack of oxygen content during combustion toxic CO/CO_2 emission is liberated to the environment. From the figure.5 A, B it shows CO/CO_2 emission were found higher at lower rpm during engine starting condition, on reaching higher rpm it is found that CO/CO_2 emission is decreased this due to the stoichiometric ratio of air-fuel mixture can be obtained optimal at higher RPM since rich mixture is need during the engine starting condition and lower RPM. This stoichiometric proportion has a significant effect on combustion temperature.

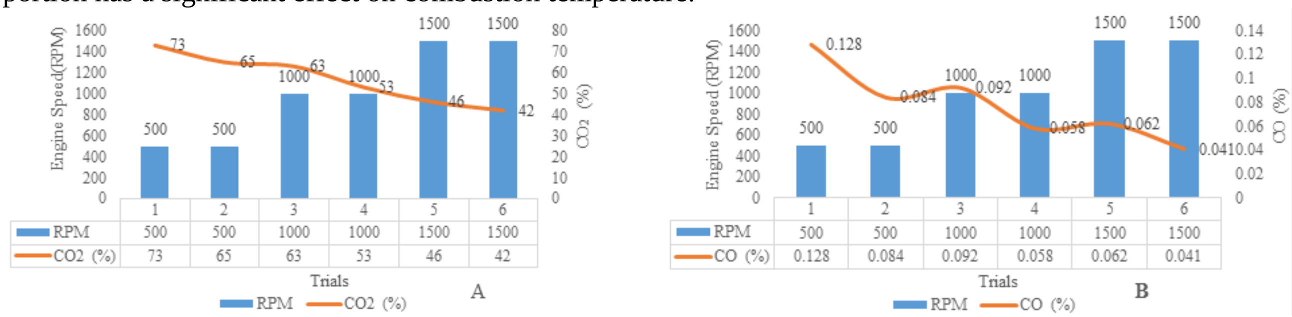

Figure.5 A, B. CO_2 & CO Emission for various rpm before implementation

Percentage of oxygen available for neat combustion also determines the CO/CO_2 emission. After oxygenating the fuel using 2-ethoxy-ethanol and 2-methoxy-ethanol, combustion process takes place with higher oxygen concentration. From Figure.6 A, B it is observed that significant control over CO/CO_2 emission is achieved by intense oxygen concentration with optimized combustion temperature.

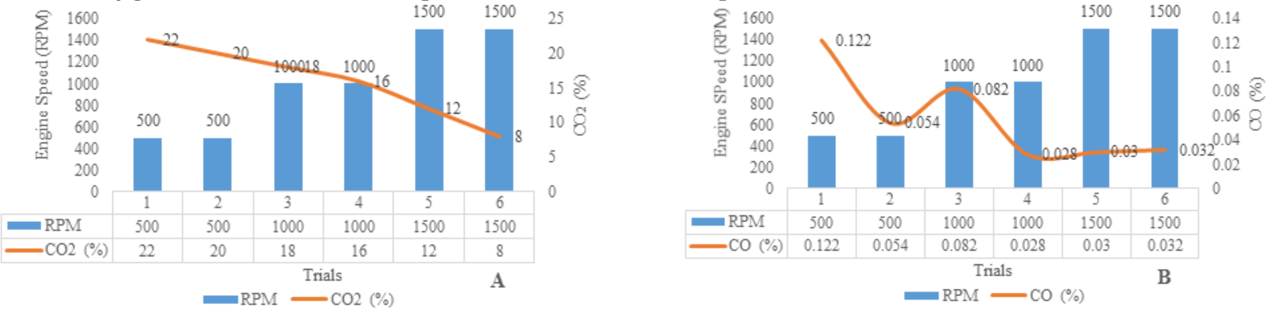

Figure.6 A, B. CO_2 & CO Emission for various rpm after implementation

Hydrocarbon Emission: HC emission observed in resulting exhaust smoke is due to uneven combustion of fuel and internal quenching takes place during combustion on the walls of the combustion chamber area. It was found that at lower rpm and zero load conditions hydrocarbon emission seems higher than at any condition. Figure.7, represents hydrocarbon emission at various rpm in different trials.

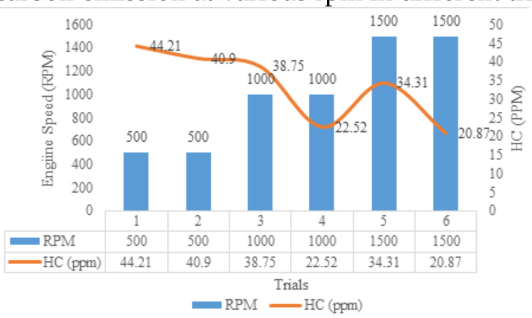

Figure.7. HC Emission for various rpm before implementation

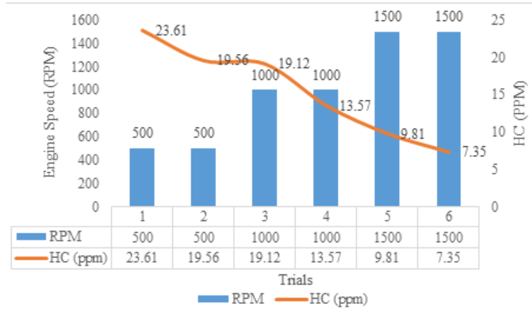

Figure.8. HC Emission for various rpm after implementation

Smoothening of combustion is achieved and it plays the key role in reducing abrupt quenching phenomenon. It can be observed from figure 8 that about 50% of hydrocarbon emission reduction is observed. This may occur due to effect of oxygenates in combustion process and optimized combustion parameters.

Table.3, shows the average reduction in smoke density and various emission proportions before and after effect of oxygenates in emission control.

Table.3. Average reduction in emission

Test		Before Implementation	After Implementation
Smoke Meter Test	Density	10.13 N%	3.89 N%
Flue Gas Analyser	HC	33.59 PPM	15.50 PPM
	CO	0.078 %	0.058 %
	CO_2	57%	16%
	NO_x	50 PPM	55 PPM

4. CONCLUSION

The following results were concluded from the above experimental investigation such as;

- The major emissions HC, CO & CO_2 seems to be decreasing through increasing rpm this may be due to increased oxygen content fuel, leading to better combustion process with optimized combustion parameters.
- NO_x emission seems increases it may be due to use-age of ethanol derivative (or) increased combustion chamber temperature due to high net heat release rate.
- Smoke density is controlled drastically of about 60%, this is due to combustion of soot particles that expels along with exhaust gas and perfect combustion.
- Emission characteristics was controlled efficiently with aid of 2-ethoxy-ethanol and 2-methoxy-ethanol in diesel emulsion.

REFERENCES

Ahmad Fayyazbakhsh, Vahid Pirouzfar, Investigating the influence of additives- fuel on diesel engine performance and emissions: Analytical modeling and Experimental validation, Fuels, 2015.

Banapurmath NR, Tewari PG, Performance, combustion, and emission characteristics of a single-cylinder compression ignition engine operated on ethanol–biodiesel blended fuels, P I Mech Eng A-J POW, 224 (4), 2010, 533–543.

Can O, Celikten I, Usta N, Effects of ethanol addition on performance and emissions of a turbocharged indirect injection Diesel engine running at different injection pressures, Energy Convers Manage, 45 (15–16), 2004, 2429–2440.

Carmen C. Barrios, Carlos Martin, Aida Dominguez- Saez, Paloma Alvarez, Manuel Pujadas, Jesus Casanova, Effects of addition of oxygenated fuels as additives on combustion characteristics and particle number and size distribution emissions of a TDI diesel engine, Fuel, 132, 2014, 93-100.

Chen H, Shuai S, Wang J, Study on combustion characteristics and PM emission of diesel engines using ester–ethanol–diesel blended fuels, Proc Combust Inst, 31, 2007, 2981–2989.

Corkwell KC, Jackson MM, Daly DT, Review of exhaust emissions of compression ignition engines operating on E diesel fuel blends, SAE Paper, 2003.

Dattatray Bapu Hulwan, Satishchandra V. Joshi, Performance, emission and combustion characteristic of a multi cylinder DI diesel engine running on diesel–ethanol–biodiesel blends of high ethanol content, Applied Energy, 88, 2011, 5042–5055.

Elina Koivisto, Nicos Ladommatos, Martin Gold, The influence of various oxygenated functional groups in carbonyl and ether compounds on compression ignition and exhaust gas emissions, Fuels, 2015.

Imtenan S, Masjuki H.H, Varman M, Kalam M.A, Arbab M.I, Sajjad H, Ashrafur Rahman S.M, Impact of oxygenated additives to palm and jatropa biodiesel blends in the context of performance and emissions characterstics of a light- duty diesel engine, Energy conservation and management, 83, 2014, 149-158.

Labeckas G, Slavinskas S, Performance and emission characteristics of a direct injection diesel engine operating on KDV synthetic diesel fuel, Energy Convers Manage, 66 (2), 2013, 173–188.

Lee SW, Herage T, Yong B, Emission reduction potential from the combustion of soy methyl ester fuel blended with petroleum distillate fuel, Fuel, 83, 2004, 1607–1613.

Mojtaba Saei Moghaddam, Abdolsamad Zarringhalam Moghaddam, Performance of an exhaust emission characteristics of a CI engine fuelled with diesel- nitrogenated additives, Chemical Engineering Research and Design, 92, 2015, 720-726.

Nadir Yilmaz, Francisco M. Vigil, Kyle Benalil, Stephen M. Davis, Antonio Calva, Effect of biodiesel–butanol fuel blends on emissions and performance characteristics of a diesel engine, Fuel, 135, 2014, 46–50.

Prommes K, Apanee L, Samai Jai-In, Solubility of diesel–biodiesel–ethanol blend, its fuel properties and its emission characteristics from diesel engine, Fuel, 86, 2007, 1053–1061.

Racopoulos CD, Antonopoulos KA, Racopoulos DC, Experimental heat release analysis and emissions of a HSDI diesel engine fueled with ethanol–diesel fuel blends, Energy, 32, 2007, 1791–1808.

Rakopoulos DC, Rakopoulos CD, Kakaras EC, Giakoumis EG, Effects of ethanol– diesel fuel blends on the performance and exhaust emissions of heavy duty DI diesel engine, Energy Convers Manage, 49, 2008, 3155–3162.

Sendzikiene E, Makareviciene V, Janulis P, Influence of fuel oxygen content on diesel engine exhaust emissions, Renewable Energy, 31 (15), 2006, 2505–2512.

Shi X, Yu Y, He H, Shuai S, Wang J, Li R, Emission characteristics using methyl soyate–ethanol–diesel fuel blends on a diesel engine, Fuel, 84, 2005, 1543–1549.

Suryanarayanan S, Janakiraman VM, Rao GLN, Sampath S, Comparative study of the performance and emission characteristics of biodiesels from different vegetable oils with diesel, SAE international powertrains, fuels and lubricants congress, Shanghai (China), SAE International, 2008.

Zhu L, Cheung CS, Zhang WG, Huang Z, Emissions characteristics of a diesel engine operating on biodiesel and biodiesel blended with ethanol and methanol, Sci Total Environ, 408 (4), 2010, 914–921.