IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
ISSN(e) : 2278-1684, *ISSN(p) :* 2320–334X, *PP : 30-35*
www.iosrjournals.org

Effect of Oxygenated Fuel Additive on Diesel Engine Performance and Emission: A Review

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ABSTRACT: *This Improvement of fuel properties essential for suppression of pollutant and optimization of engine performance. One way is use of additives. Oxygenated additives were conventionally recommended for gasoline. But now day's oxygenated additives are widely considered for diesel fuel also. This paper reviews the available oxygenated additives and compares their effect on exhaust gas emission with help of conference papers and journals. During study of available material It is found that , oxygenated are effective method for reducing PM, CO and HC without significant increase in the NOx emission.*

Keywords *- Diesel, emission, Oxygenated additive, NOx , performance*

I. INTRODUCTION

Due to low cost of Diesel fuel , diesel engine are more common and economical than gasoline engines but suffer from inherent higher Particulate Matter(PM) and nitride oxide (NOx) emissions. Reduction of exhaust emissions is extremely important for diesel engine development in view of increasing concern regarding environmental protection and stringent exhaust gas regulations. Diesel engines are the major contributors of air polluting exhaust gases such as particulate matter, carbon monoxide, oxides of nitrogen and other harmful compounds. Increasingly stringent regulations governing particulate emissions, nitric oxides from diesel engines have prompted research directed toward methods for reducing the in-cylinder formation of pollutants by modifying fuels or controlling particles by after treatment technologies. The diesel fuel properties have become even more stringent controlling diesel exhaust emissions through fuel modification seems to be promising because it would affect both the new and old engines. Modification of diesel fuel to reduce exhaust emission can be performed by increasing the cetane number, reducing fuel sulphur, reducing aromatic content, increasing fuel volatility and decreasing the fuel density to have the compromise between engine performance and engine out emissions, one such change has been the possibility of using diesel fuels with oxygenates. These blends usually enhance the combustion efficiency, burn rates, power output, and the ability to burn more fuel, but first of all, these blends offer the reduction of exhaust emissions The reduction of diesel engine emissions could be considered from three aspects: the combustion improvement technique, the exhaust after treatment technology, and the fuel melioration. However, the relevant research on fuels especially on liquid fuels was still less investigated until very recently. The research on dimethyl ether (DME) as an alternative fuel produced great enlightenment. DME contains oxygen element and has no C–C bonds, which therefore helps to achieve smokeless combustion that is superior than with a diesel fuel even without high-pressure injection or turbocharger, however, the use of DME requires significant modifications on the fuel supply, delivery, and injection systems, which largely limits its application. The blending of oxygenates into a diesel fuel could effectively reduce the smoke emission from diesel engines, which has a strong synergy to the use of methanol, ethanol, or dimethyl carbonate (DMC). The studies are carried out on a set of paper on oxygenated fuels, which include DMC, diethylene glycol dimethyl ether (DGM), and diethyl succinate (DES). The results indicated that the smoke emission decreased linearly as the oxygen content increased and notably near zero smoke emission was attained when the oxygen content was higher than 30%.

II. LITERATURE SURVEY

The investigation was carried out by T. Nibin, A. Sathiyagnanam and S. Shivprakasam, 2003 to improve the performance of a diesel engine by adding oxygenated fuel additive of known percentages as discussed in [1]. The effect of fuel additive was to control the emission from diesel engine and to improve its performance. The fuel additive dimethyl carbonate was mixed with diesel fuel in concentrations of 5%, 10% and 15% and used. The experimental study was carried out in a multi-cylinder diesel engine. The result showed an appreciable reduction of emissions such as particulate matter, oxides of nitrogen, smoke density and marginal increase in the performance when compared with normal diesel engine as discussed in [1]. J. Wang, J. Xiao and S. Shuai, in paper [2] presented in 2009 explores the possibility to significantly reduce the particulate matter (PM) emissions by new fuel design. Several oxygenated blends were obtained by mixing the biodiesel, ethanol, and Dimethyl carbonate (DMC), and diesel fuels. The tests were conducted on two heavy-duty diesel engines, both with a high-pressure injection system and a turbocharger. The total PM and its dry soot (DS) and soluble organic fraction (SOF) constituents were analysed corresponding to their specific fuel physiochemical properties.. The fuels used in this study include a baseline diesel fuel, three types of biodiesels, and their blends with ethanol, DMC, DMM, and straight-run (or directly distilled) diesel fuel. Ethanol, DMC, and DMM are used as oxygenates to raise the oxygen content, while the straight-run diesel fuel is used to improve the auto-ignition capability of the blended fuel. When fuelling oxygenated blends, the direct soot constituent in PM emissions decreases significantly as the fuel oxygen content increases. However, when the oxygen content reaches 15% or higher, reduction rate becomes slow This experiment was carried out by H. Hess, A. Boehman and J. Perez on six cylinder diesel engine by using a diesel fuel reformulating agent, CETANER, has been examined in a popular light-medium duty turbo diesel engine over a range of blending ratios as discussed in paper [3]. As much as an 83% reduction in particulate mass emissions was observed and the impact of the additive on gaseous emissions is not as clear, with substantial scatter observed in CO and total hydrocarbon emissions. Emissions of NOx were consistently lower for all CETANER blend ratios, although the trend with increasing CETANER concentration is noisy and examination of the combustion process through in cylinder pressure trace analysis showed only a slight decrease in peak pressure and a slight increase in combustion duration, with no significant change in ignition delay [3]. K.I. Burshaid A, M.A. Hamdan in their paper [4] found that methanol has significant effect on the reduction of soot formation and acetone has least effect on the same. Bhavin H. Mehta, Hiren V Mandalia in paper [5] discussed about properties of synthetic oxygenates and ther effect on emission from engine and found that oxygenates play good role in reducing PM, CO, and HC without increase in NOx emission.

III. 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.

3.1 Requirements of Good Oxygenate Properties

- Oxygenates that are to be blended with diesel fuel must have fuel properties appropriate for motor fuel. In particular
- The oxygenate must be miscible with various diesel fuels over the range of environmental temperature seen in vehicle operation.
- Must have an adequate cetane number and preferably allow the blend to show an increased cetane number. Minimum volatility when mixed with different blend of diesel

3.2 Selection of oxygenates

The selection of oxygenates was guided by several considerations. The oxygenate boiling point was required to be in the range of temperatures commonly observed for diesel fuel components and the flash point to meet commonly adopted diesel fuel fire safety requirements ,Necessary requirements, concerning fire safety and combustion properties of the pure substances defined the elimination criteria for the first selection.

Boiling point › 60 0 C,

Flash point › 55 0 C,

Self ignition temperature ‹ 350 C,

Kinematic viscosity ‹ 4 mm2 /s.

In addition other criteria (e.g. oxygen content, density, lower heating value ...) were set to choose the more suitable oxygenated additives in reducing the exhaust opacity of automotive diesel engines.

3.3 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 and THF [5].

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.[5]

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 carbonylation of methanol with carbon monoxide and oxygen, instead of from phosgene. This allows dimethyl carbonate to be considered a green reagent.[3][5]

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.[4]

Ethyl tert-butyl ether (ETBE) can be synthesized by reacting bio-ethanol (47% v/v) and isobutene (53% v/v) with heat over a catalyst, It can be considered a ‘‘bio-fuel”, therefore ETBE helps to reduce the vehicle-out carbon dioxide (a green house gas) introduced to the atmosphere. As an additive to gasoline, ETBE has been extensively examined with regard to its impact on exhaust emissions, exhaust gas after treatment systems, evaporative emissions, cold storability, materials used in the fueling systems and others in spark ignition engine-powered vehicles . The fundamental characteristics regarding to ignition and combustion of both the pure ETBE and ETBE blended fuels have been studied as well . ETBE has the properties of low auto-ignitability, low boiling point, oxygenated, and infinite solubility in diesel fuel. Therefore, ETBE, as an additive to diesel fuel, has the potentials for suppression of the smoke emissions increasing with EGR and extending smokeless and low NOx diesel combustion to higher loads by promoting fuel–air mixing as well as by its oxygenated property. Nevertheless, some concerns should be addressed when using ETBE as an additive to diesel fuel. For instance, the lowered fuel cetane number due to addition of ETBE causes a too high rate of in-cylinder pressure rise and deteriorates thermal efficiency or fuel economy. In addition, it is concerned that addition of ETBE to diesel fuel, like ethanol addition to diesel fuel, might cause some increases in unregulated toxic emissions such as carbonyl or aldehyde emissions [7]. Ethylene Glycol Môn acetate (EGM), and its effects on the characteristics of performance and emission of a compression ignition engine. The results show that the engine power outputs decrease and the BSFC increase when the diesel engine fueled with blends, but the diesel equivalent BSFC decrease. The results also indicate that all oxygenated fuels tested in this study show a beneficial effect on reducing smoke emissions at the operation conditions compared with diesel fuel. With the EGM15, an average smoke reduction of 49.9% and a maximal smoke reduction of 71% are obtained. The blends have little effects on the NOx emissions at most loads. The CO emissions of the EGM diesel blends decrease obviously at high load. All these results indicate the potential of EGM-diesel blend for clean combustion in diesel engine [9].

IV. TESTING METHODOLOGY

4.1 Experimental Setup

A single-cylinder, 4-Stroke, water-cooled diesel engine setup as shown in fig 4.1.1 at rated power will be considered for the purpose of experimentation. The engine is coupled to a rope brake dynamometer through a load cell. It is integrated with a data acquisition system to store the data for the off-line analysis. The effects of oxygen enrichment in base fuel on diesel combustion and emissions will be studied separately at different loads in a DI diesel engine at constant speeds. Oxygenated fuel additive will be added in diesel at different proportion and its effect on engine performance and emission will be measured.

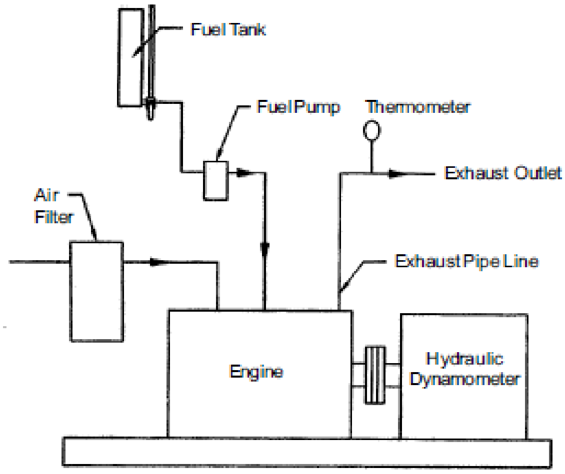

Fig. 4.1.1 Experimental Setup

4.2 Instrumentation Details

The test engine is coupled to an eddy current dynamometer. The main measuring instruments were ; a viscous type laminar air flow meter, tanks and flow meter for fuels, temperature sensors for the exhaust gas, inlet air, cooling water, lubricating oil, a TDC marker (a magnetic pickup), a rpm indicator, and a kistler piezo electric transducer for the combustion chamber pressure, and a data acquisition system. Exhaust gas analyzers were used to measure smoke, nitrogen oxides (NOx), total unburned hydrocarbon (HC), and carbon monoxide (CO) at the exhaust pipe

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V. EXPERIMENTAL PROCEDURE

In most of paper, the engine tests were conducted at a constant engine speed. After stable operating conditions were experimentally achieved, the engines were subjected to similar loading conditions. Starting from no load the observations were recorded at 20%, 40%, 60% and 80%, all as percentages of the rated load. The engine was stabilized before taking all measurements. All measurements were taken at constant static injection timing. An attempt was made to conduct all experiments without significant fluctuations in inlet air temperature and lubricating oil temperature as a method to prevent possible discrepancies in engine operation during the tests and mainly, to avoid variations in engine loading. The experimental procedure consisted of the following three steps;

- Initially, engine tests using the base reference diesel fuel were conducted covering all engine loads examined to determine the engine operating characteristics and pollutant emissions constituting the engine base line operations.
- The previous procedure was repeated at the same operating conditions with the engine fueled consecutively with fuels of different additives.

- Emphasis was made to confine and if possible to diminish the scattering of the measurements for pollutant emissions around the mean value by repeating the measurements at each operating conditions.

During the engine tests the following parameters were recorded at each operating conditions considered.

1. Exhaust gas temperature
2. Fuel consumptions.
3. Exhaust smokiness
4. Exhaust gas emissions

VI. OBSERVATIONS

After literature survey, it is found that different oxygenated additive has different effect on engine performance which has compare in table 6.1

Table 6.1 Effect of Oxygenated Additive on performance of diesel Engine

Component	**Smoke Density**	**CO**	**HC**	**O2**	**NOX**	**EGT**
DPE 15		🟢	🟢			🟢
DIGLYME		🟢	🟢		🔴	🟢
MTBE	🟢	🟢	🟢		🔴	
ETBE WITH EGR	🟢				🟢	
ETHANOL FUNGMINTATION	🟢	🔴	🔴			
DMC	🟢	🟢	🟢			
7.5% EGM + 7.5% DCM	🟢		🟢			
2-MEA	🟢		🟢	🟢	🔴	
Octylated Butylated Diphenlamine antioxidant		🟢	🟢		🟢	
15 DME+ 10 Biphenyl Ether		🟢	🟢			

🟢 Improvement 🔴 Decrease

VII. CONCLUSION

The characteristics of performance and emission of a compression ignition engine fuelled with different oxygenated fuel diesel blends were investigated and compared with those fuelled with diesel fuel as shown in table in 6.1. It is observed that Brake thermal efficiency increases, the oxygen enrichment provided by the additive leads to smoke reduction. The smoke reduction rate and smoke emission show linear relationship with additive percentages. Smoke is reduced by 20 % for 5 % of additive addition. It can be observed that NOx increases with increase in brake power. It can be seen that 5% additive added to diesel fuel, considerably increases the NOx emission when compared to the normal diesel engine. The increase in NOx with DMC added may be caused by the high temperature promoted by combustion and oxygen enrichment. It can be observed that soot increases with increasing the brake power. It can be seen that 5% DMC added to diesel fuel effectively reducing the soot by 52 %.So oxygenated additive reduces HC, CO, particulate matter and improve efficiency. But main drawback is increase in NOX emission. Various oxygenated fuel additives are available which posses more oxygen content compared to diesel. If these additives are added in diesel at appropriate proportion it will improve the engine performance and emission characteristics. If the proportion of these additives is more than engine performance declines because the additives have lower calorific value compared to diesel. Other barriers in the use of oxygenated fuel additives are their high price and poor availability.

VIII. ACKNOWLEDGEMENTS

I took this opportunity to thanks my guide, colleagues and family since without their support it's not possible for me to complete this paper. Then I like to thanks Prof. A. D. Desai, HOD, mechanical dept. P E S Modern college of engineering, Pune and Dr. L. G. Navale, Princiapl, M E S College of Engineering for the motivation and support. Also I like to give sincere thanks to Dr. S. H. Gawande for his valued guidance for correction technical aspects and formatting of paper. At last I like to thanks my family for whom I was not able spare time due to my busy schedule still supported me to finish my work.

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