Need of Composite Additives for Diesel Fuel : A Review

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Abstract

The improvement of fuel properties is essential for suppression of pollutant and optimization of engine performance. One way is use of additives. Literature survey shows that there is considerable work done on fuel additives. This paper reviews the effect of different additives on diesel engine performance and emission. Through the study of literature survey, effect of different additives has been studied and trying to find the scope for new composite additives having better performance in respect of engine performance and emission control. This study shows that individual additive has good effect on some fuel properties while adverse effect on other. So to achieve complete control on engine performance and emission control, there is need of composite additive and more research is needed.

1. 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 additives. 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 limitation of individual additive is that while it is improving certain fuel properties, it has adverse effect on other performance. The problem connected to improvement in combustion have neither been faced nor resolved in organic way. These engines do not burn their fuel completely resulting in unburned hydrocarbon particle in atmosphere. In subsequent section, effect of different additive on diesel engine has been studied and compared.[14],[1],

2. Literature Survey

Nubai M. Ruberio, Angelo C Pinto and their team has done extensive review work on effect of fuel additive on diesel fuel and blended diesel fuel. They found that different additive have different effect on diesel fuel. For blended diesel fuel Cetane enhancer additive is needed to maintain its original thermal properties.[1]

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. 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 [14].

Paper prepared by J. Wang, J. Xiao and S. Shuai, 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. A blended fuel that contains biodiesel, DMC and high Cetane number diesel fuels was chosen eventually to enable the diesel engines to meet the Euro IV emission regulation. Based on the test results, the basic design principles were derived for the oxygenated blends that not only need the high oxygen content, but also the high Cetane number and the low sulphur and low aromatic contents. 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 fueling 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 [2][14].

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 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 Cetane blend ratios, although the trend with increasing Cetane 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][14]

3. Fuel Additives

The main Fuel additive is nothing more than chemical compound that has desire physio chemical properties which help in improving engine performance and emission control. It helps fuel to burn more efficiently and reduces some types of atmospheric pollution. It can also reduce deadly carbon monoxide emissions and smog formation.

Some additive 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.

3.1 Requirements of Good Additive Properties:

Additives that are to be blended with diesel fuel must have fuel properties appropriate for motor fuel. In particular

- It must be miscible with various diesel fuels over the range of environmental temperature seen in vehicle operation.
- The blend must exhibit an adequate water tolerance.
- 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 Additive:

The selection of additive was guided by several considerations. The additive 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 additives in reducing the exhaust opacity of automotive diesel engines.

4. Types of Fuel Additives:

Dimethoxyethane, also known as glyme, monoglyme, dimethyl glycol, ethylene glycol dimethyl ether, dimethyl cellosolve, and DME, is clear, colorless, aprotic, and liquid ether that is

used as a solvent. Dimethoxyethane is miscible with water. Dimethoxyethane is often used as a higher boiling alternative to diethyl ether and THF. Dimethoxyethane forms chelate complexes with cations and acts as abidentate ligand.

2-Ethylhexyl Acrylate is water white liquid with a characteristic odour. It is supplied inhibited to preventpolymerization. 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 carbonylation 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.[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 fuelling 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 Monoacetate (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 fuelled 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].

5. Experimental Procedure

In most of literature, the engine tests were conducted at a constant engine speed of 2000 rpm. 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:

a) 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.

b) The previous procedure was repeated at the same operating conditions with the engine fuelled consecutively with fuels of different additive

c) 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.

d) The observation table of all the literature were studied and additives were compared on following basis taking their maximum effective blending percentage.

During comparison following parameter were taken for comparison.

- Exhaust gas Emission
- Fuel consumptions.

6. Observation Table:

After doing literature study, effect of different additive on diesel fuel has been observed and put in comparative chart to get broad idea about which additive is more suitable and what effect it has on engine performance and emission control

Additive	Smoke Density	CO	HC	CO_2	NO_x	EGT	SFC
DPE 15		◎	◎			◎	
DIGLYME		◎	◎		●	◎	
MTBE	◎	◎	◎		●		
ETBE WITH EGR	◎				◎		
Ethanol Fung.	◎	●	●				
DMC	◎	◎	◎				
EGM			◎		●		◎
7.5% EGM + 7.5% DCM	◎		◎				
2-MEA	◎		◎	◎	●		
OCTYLATED BUTYLATED DIPHENLAMINE ANTIOXIDANT		◎	◎		◎		
15 DME+ 10 BIPHENYL ETHER		◎	◎				
HYDROGEN		●			●	●	
METALLIC ADDITIVE		◎		●	◎	◎	

Table 6.1 Effect of Oxygenated Additive on performance of Diesel Engine[1]-[14]

7. Conclusion:

The characteristics of performance and emission of a compression ignition engine fuelled with different fuel additive diesel blends were investigated and compared with those fuelled with diesel fuel. It is observed that most of additive individual effect particular parameter while hampering the other. So there is needed to combine different additive together so it will have positive effect on all parameter. After doing details review, it concluded that the resultant composite should contain

- Oxygenate to reduce CO, HC, smoke
- Reducing agent to limit formation of NOx
- CN improver to compensate loss of CN due to addition of additive and also improve thermodynamic properties.

So there is lot of scope for future work in composite additive in selecting correct additive and in correct proportion which give best effect on engine performance and emission control.

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