Effect of Performance and Emissions on DI Diesel Engine Using Ethanol Diesel Blends- A Review

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Abstract

Ethanol is a renewable source of energy because its sources are derived from bio-based. Due to the limited source of petroleum fuel and increasing cost rapidly day to day needs to generate substitute source of petroleum diesel fuel. The addition of ethanol in diesel fuel decreases high heating value, cetane number, aromatics fractions and kinematic viscosity of ethanol blended diesel fuels and changes distillation temperatures. An additive used to maintain blends stability and homogenous and an ignition improver also to be used, which can improve cetane number of the blends, have favorable effects on the physicochemical properties associated to ignition and combustion of the blends.

The main aim of the present review is to study the effect of performance and emission characteristics of blended fuels on a DI diesel engine. The ethanol diesel blends decreases the brake thermal efficiency, brake torque, and brake power while increase the brake specific fuel consumption. At high loads, the blends minimize smoke significantly with a small penalty on CO, acetaldehyde and unburned ethanol emissions compared to diesel fuel. NOx and CO_2 emissions of the blends are reduced fairly. At low loads, the blends have small effects on smoke reduction due to overall leaner mixture. With the aid of additive and ignition improver, CO, unburned ethanol and acetaldehyde emissions of the blends can be minimized moderately, even total hydrocarbon emissions are fewer than those of diesel fuel. The results indicate the potential of diesel reformation for clean combustion in diesel engines.

Keyword

Alternative Fuels, Ethanol, CI (Diesel) engine, Performance and emission.

Contents

INTRODUCTION

As a result of rapid increase in the demand and prices of petroleum oil, a number of current studies have focused on the development of alternative fuels for transportation. In addition, high emissions of CO_2, NO_x, SO_2 and particulate matter (PM) are produced during fossil fuel use, generating environmental problems. These facts have converged in the search of renewable energies, such as biofuels. The lack of conventional fossil fuels, their increasing costs and rising emissions of combustion-generated pollutants will make bio-based fuels more attractive [1]. Due to the rise in price of petroleum products, especially after the petrol crisis in 1973 and then the Gulf War in 1991, geographically reduced availability of petroleum and more rigorous governmental regulations on exhaust emissions, many researchers have studied alternative fuels and alternative solution methods [2, 3].

The world's dependency and skyrocketing global energy requirement coupled with the foreseeable future depletion of the worldwide petroleum reserves has paved the way for use of alcohols as an alternative cleaner fuel [4,5]. Most of the internal combustion (IC) engines utilize petroleum fuels. The source of petroleum fuels are limited and it is to be exhausted in about 40 years. Limited energy sources warn of potential lack of energy in the future [6]. IC engines are consumed around 35% of the petroleum fuels and exhausts emitted from these engines are one of the major causes of the environmental pollution [1]. Biodiesel is one of the alternatives that have attracted much concentration because most of transport vehicles are diesel-operated. The potential impact of biodiesel tradition on the economy is obvious. However, biodiesel has its many advantages over petro-diesel biodiesel has widely used because of its limited production. Another substitute biofuels of diesel is ethyl alcohol (ethanol) has a much larger resource base on its production in various countries including India.

There are many studies on the use of alcohols in spark ignition (SI) engines [7-12]. In the past little attention has been given to the utilization of alcohols in compression ignition (CI) engines. The difficulties encountered while attempting to use alcohols in CI engines, especially at high alcohol ratios, which are summarized as follows [13].

1.) Alcohol contains less heating value in comparison to diesel fuel therefore additional alcohol required than diesel fuel by mass and volume.

2.) Large proportion of alcohol could not mix with diesel fuel homogeneously hence use of diesel-alcohol blends at large a ratio of alcohols is not suitable. Also the blends were not stable and separate in the presence of a trace amount of water.

3.) The cetane numbers of Alcohols have extremely low whereas the diesel engines are favor to high cetane number fuels (45–55) that can auto-ignite easily and give minute ignition delay.

4.) The poor auto-ignition capacity of alcohols is accountable for severe knock due to fast burning of vaporized alcohol and combustion quenching caused by high latent heat of vaporization and subsequent charge cooling.

Bioethanol is formed from bioderived materials such as sugarcane, molasses or cassava root has lower production cost, and is environmentally friendly [14].

As one kind of renewable alternative fuels, ethanol could be produced by alcoholic fermentation of sugar from vegetable materials, such as corn, sugar cane, sugar beets, or agricultural residues [3]. Due to adding its high concentration of the oxygen, ethanol has an advantage of minimizing soot emissions.

Since ethanol has used as a fuel for compression ignition (CI) engines from 19th century. Ethanol can be fermented and distilled from biomasses. Therefore, it can be considered as a renewable fuel. As a fuel for diesel engines, ethanol has a number of advantages over diesel fuel such as the reductions of soot, carbon monoxide (CO) and hydrocarbon (HC) emissions. Although ethanol has many advantages it cannot use extensively due to limitations in technology, economic and regional considerations. However, ethanol blended diesel fuels can be practically used in CI engines [3, 15].

Ethanol has some limitations such as lower flash point and lower miscibility which may cause phase separation. Ethanol is immiscible in diesel over a wide range of temperatures. It can be used without much modification in the diesel engine. [16].

Ethanol is an oxygenated component that increases the percentage of oxygen during the combustion and reduces the smoke and particulate emissions in the exhaust [17].

Ethanol was initially investigated in the 1970s in South Africa and continued in Germany, Australia, and the United States during the 1980s [18]. Previous studies [19-21] showed that diesohol has the potential to be used in regular engines without any modification. Diesohol, consisting of 89% low-sulfur No. 2 diesel, 10% ethanol, and 1% additive, showed the same performance as regular diesel on an International 7.3L engine with a slight decrease of 4% in power due to its lower heating value [19]. Ethanol contains low cetane number leads the fuel to increase ignition delay and greater rates of pressure rise that results in high peak combustion temperatures and higher peak cylinder pressures. This high peak temperature increases NO_x emission [22].

Cetane value is most important factors for the evaluation of fuel ignition ability of ethanol. The cetane value of pure ethanol is 8, which makes the cetane value of the EDBF lower than that of pure diesel. The ignition ability of ethanol-diesel blended fuel is worse than that of pure diesel and will further lead to poor combustion performance and degraded exhaust emission. In the Based on engine combustion visualization and in-cylinder temperature field analysis using the primary color method [23]. Reported that the ignition ability is increased by using EDBF but the luminosity of the flame and total combustion duration are minimized and the peak combustion temperature is reduced. The effect of additives on the compatibility of diesel and EDBF has been studied.

The influence of CI additives on the characteristics of blended fuel (volatility, flashpoint, and distillation curve) and the reduction of the cetane number were presented [24]. Studied the combustion characteristics of an ethanol - diesel fueled compression ignition engine with and without CI. It has been found that ignition ability and combustion performance can be improved markedly by adding CI to the blended fuel. CI was helpful for improving ignition delay, maximum rate of pressure rise, cylinder peak pressure, and combustion noise. Adding CI of 0.2% volume of the fuel, the combustion performance of one EDBF can be improved equivalent to that blended fuels that contain 10% less ethanol [24].

[25] Concluded that the addition of ethanol to the diesel fuel results in different physicochemical changes in diesel fuel properties, especially decrease in viscosity, heating value and cetane number. Therefore, different techniques concerning ethanol–diesel fuel operation have been developed to make the diesel engine technology compatible with the properties of ethanol-based fuels [26]. Stated that of the fuel economy and reduction of pollutant emission of diesel engines is improvement by technique of emulsification is one probable approach. The best emulsified ratio of 50D: 50E has been prepared based on the water-in oil- type emulsion method [27].

From the investigation, it is found that when the engine operated with oxygen-enriched additive-added emulsified fuels, with the preferred emulsified fuel ratio of 50D: 50E, the greatest performance of engine improves it brake thermal efficiency (BTE) and reduce the specific fuel consumption (SFC), SD, PM, NO_x is reach by In order to meet the requirements of emission regulations and minimize the exhaust emissions of engines. Many investigations on the effects of CI on the exhaust emissions of EDBF-fueled compression ignition diesel engines have been carried out [23, 28-31]. Huang and Lu¨ and coworkers reported that the Cetane improver has a positive effect on CO and NO_x emission and negative effect on hydrocarbon (HC) emission. The smoke emission maintained at the same level as that in the condition without the cetane number improver.

[15] Experimentally investigated the performance and emissions of a turbocharged and indirect injection CI engine the effect of ethanol addition (10% and 15% in volume) to No. 2 diesel fuel and found that the ethanol addition minimizes smoke cloudiness, CO and SO_2 emissions. The addition of ethanol in diesel fuel is a reason of increase NO_x emissions and poor power production.

Due to the high fuel density of biodiesel the spray and atomization characteristics of biodiesel fuel has a small and long spray tip penetration and has a narrow spray cone angle compared to the conventional diesel fuel [32-33].

There are many utilizations of ethanol in diesel engine [34-35]. And the most suitable technique of uses of ethanol in the diesel engine is blending ethanol and diesel with a solubilizer to form consistent and stability blend fuels. It was obtained that if the volume percent of ethanol is > 5%, some performance and efficiency losses have occurred [3].

2. Blend properties

There are various fuel properties that are necessary to the appropriate operation of a diesel engine (CI). The blend of ethanol to diesel fuel influences certain properties with particular reference to blend stability, lubricity, viscosity, Cetane number and energy content. Materials compatibility and corrosiveness are important factors that need to be considered. Properties of fuel that affect safety should be leading in any fuel evaluation. These include flashpoint and flammability. The biodegradability of fuel has turn into a significant factor with respect to ground water contamination.[36]

2.1 Blend stability

The solubility ethanol and diesel is mainly affected by two reasons water content and temperature of the blend [36]. At mild ambient temperatures dry ethanol blends readily with diesel fuel. However, two fuels separate below about 10°C, a temperature limit that is simply exceeded in many fractions of the world for a huge part of the year. This separation can be prevented proficiently in two ways:

(i) By adding an emulsifier which acts to suspend small droplets of ethanol in the diesel fuel.

(ii) By adding a co-solvent that acts as a bridging agent through molecular compatibility and bonding to produce a homogeneous blend [37].

Emulsification generally involves heating and blending steps to produce the final blend while co-solvents permit fuels to be 'splash-blended' consequently simplifying the blending procedure [38]. Developed formulations of two micro-emulsion surfactants:

(i) ionic and (ii)detergent less

Blends of these surfactants with aqueous ethanol and diesel were visible and stable at temperatures as low as) 15.5^{o}C. Many researchers in Sweden tested a blend of 15% aqueous ethanol (5% water) with diesel containing DALCO, an emulsifying agent developed in Australia. The solubility of ethanol in diesel is also affected by aromatic content of diesel [39]. and therefore the effectiveness of co-solvents and emulsifiers. Ethanol having polar character which makes a dipole in the aromatic molecule and allowing them to interact reasonably strongly while the aromatics remains compatible with other hydrocarbons in diesel fuel. Current studies in the USA have made use of additives from three different manufacturers. Pure Energy Corporation of New York was the first manufacturer to develop an additive package that allowed ethanol to be splash-blended with diesel fuel using a 2-5% dosage with 15% anhydrous ethanol and proportionately less for 10% blends [40].

2.2 Materials compatibility

The use of ethanol in gasoline engines in the early on 1980s resulted in various materials compatibility studies, many of which are also appropriate to the effect of ethanol–diesel blends in diesel engines and particularly in the fuel injection system. The quality of the ethanol has a strong influence on its corrosive effects [41]. In addressing the problems of ethanol corrosion related with gasoline blends, Brink et al. (1986) separated ethanol corrosion into three categories:

(i) General corrosion (ii) Dry corrosion and (iii) Wet corrosion

General corrosion was due to ionic impurities, mainly acetic and acid chloride ions. Dry corrosion was credited to the ethanol molecule and its polarity [42]. Analysis reports of dry corrosion of metals by ethanol and found that lead, aluminum and magnesium, were susceptible to chemical attack by dry ethanol. Wet corrosion is due to azeotropic water, which oxidizes most metals [43]. Dry ethanol would be expected to have fairly minute corrosive effect when blends containing neutral pH value. The ethanol permits to absorb moisture from the atmosphere when a blend containing in a tank for enough time, it can tend to be more corrosive as it passes through the fuel injection system. Fuel injection pump contains the fuel for a number of months, for example in a combine harvester engine; therefore it is allowing the fuel time to corrode parts of the fuel pump internally. Corrosion inhibitors have been incorporated in some additive packages used with ethanol–diesel blends [42]. Ethanol has also affected the non-metallic components with particular reference to elastomeric components such as O-rings and seals in the fuel injection system. These seals tend to swell and stiffen. Resin-sealed or resin-bonded components also are vulnerable to swelling and seals may be compromised [44].

2.3 Energy content

The energy content of a fuel has a direct influence on the power output of the engine [45]. Stated that the ethanol-diesel blends to have gross energy contents at least 90-95% of that for No. 2 diesel to allow existing engines to deliver sufficient power for the loads for which the vehicle is designed. The energy content of ethanol diesel blends reduce by about 2% for each 5% addition of ethanol by volume, assuming that any additive included in the blend has the same energy content as diesel fuel.

2.4 Cetane number

The minimum cetane number specified by ASTM Standard D 975-02 for No. 2 diesel is 40. Typical No. 2 diesel fuels have cetane numbers of 45–50. With the inverse relationship of octane number and Cetane number, ethanol exhibits a low cetane rating therefore increase the concentrations of ethanol in diesel results the lower cetane number proportionately. The ignition characteristics of ethanol–diesel blends was unreliable, because of inconsistencies in the determination of cetane numbers below 30 is explain with cetane numbers [46]. However, they estimated that the cetane number of ethanol was between 5 and 15. Lower cetane numbers denote longer ignition delays and permits additional time for fuel to vaporize before starts the combustion. Initial burn rates are higher resulting extra heat release at constant volume that is more efficient conversion process of heat to work. The difference in cetane numbers between ethanol-diesel emulsions and stable blends of aqueous ethanol and diesel containing no additive is established by [47]. The emulsified ethanol had less effect on cetane than the ethanol in solution. They thought that this was due to a shielding effect of the emulsion structure delaying evaporation of the alcohol from the fuel droplets, while in the solution, the ethanol molecules were free to evaporate immediately.

A number of ignition improvers are available for ethanol fuel with special emphasis on biomass-derived nitrates. They noted the energy release per equivalent nitrate on the molecular weight of the ignition improving nitrate has an important dependence [48].

2.5 Safety and biodegradability

During handling and storage is concern with the flammability of alternative fuels when these are considering their introduction into existing facilities. The vapor produced by the evaporation of motor fuels can produce flammable situation in partly filled fuel tanks during refueling, and when damage or leakage occurs in tanks or other fuel system components [49]. Fuel vapors will produce in the fuel tank headspace due to the increasing temperatures which progress from too-lean-to-burn, to combustible, to too-rich-to-burn [50]. Fuel flammability is typically described in terms of its flashpoint and flammability limits. Flammability limits are the minimum and maximum concentrations of combustible vapor in air and the temperatures at which the vapor arise that the flame will propagate after enough ignition energy is provided [51]. Flashpoint is the lowest temperature at which the vapor pressure of a liquid is adequate to produce a flammable mixture in the air over the liquid surface within a vessel.

A comparison of these variables for neat diesel fuel, neat ethanol and neat gasoline are in Table 1, which results that the ethanol fells between diesel fuel and gasoline in terms of flashpoint and flammability temperature limits. However, both the minimum and maximum concentration limits were higher than those for diesel fuel and gasoline. The result of external sparks, static discharge or smoking materials are a key hazard of the higher flammability limits is ignition of the plume of vapor leaving the tank during refueling as [48]. Due to the higher conductivity of ethanol, ethanol-diesel blends have static discharge which can not be as much of an issue. For the safe storage and handling of flammable liquids the guidelines has established by the National Fire Protection Agency (NFPA) the discerning fuel property is the flashpoint [50].

Table 1[50].

Approximate fuel characteristics related to flammability of neat diesel fuel ethanol and gasoline

Fuel characteristics	Neat diesel	Neat ethanol	Neat gasoline
Vapour pressure at 37.8^{o}C(kPa)	0.3	17	65
Flash point (^{o}C)	64	13	- 40
Auto-ignition temperature(^{o}C)	230	366	300
Flammability limits (%)	0.6-5.6	3.3-19.0	1.4-7.6
Flammability limits (^{o}C)	64-150	13- 42	-40 to18

3. Performance and emission of CI engine using ethanol & its blends

3.1 Performance

The brake-specific fuel consumption (BSFC) of the engine shows in Figure 1 when fueled with diesel and the ethanol blends with the variation in engine load at 1500 rpm. As the plot shows an average reduction of 2.7% when blend B5b used, whereas blend showed B3s approximately same fuel consumption as diesel. The decrease in fuel consumption of B5b is due to the oxygenated additives present in ethanol and biodiesel, which promotes combustion. When the engine is fueled with B5b (oxygenated blend) adequate oxygen is present in the cylinder that oxidizes the fuel completely resulting in reduction of fuel consumption for generation of similar brake power as diesel (Heywood, 1988).

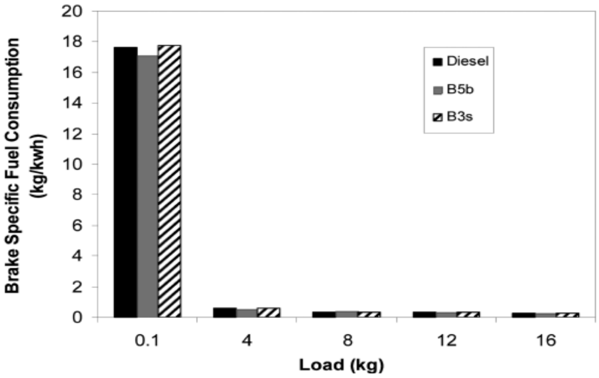

Figure 1. BSFC Vs Load

The torque output checked by the same model engine with two blends containing 10% and 15% dry ethanol respectively and 2% Betz-Dearborn additive, and reported an approximate 8% reduction for both fuel blends [52]. It has reported when 30% ethanol-diesel blend used in a tractor engine fitted with a rotary distributor pump evaluating a 5% drop in maximum fuel delivery. They adjusted the maximum fuel delivery setting on the pump to partly restore the power lost from reduced energy content and fuel pump leakage. A 15% dry ethanol, 2.35% PEC additive and 82.65% No. 2 diesel fuel blend run in a Cummins 5.9 L engine the brake thermal efficiency increases by about of 2 – 3 % at rated speed. Measured a 7-10% decrease in power at rated speed [53].

Figure 2 demonstrated the air-fuel ratios (A/F) of blends and neat diesel and it is observed that the ratio decreases with increase in load clearly due to the naturally aspirated CI engine the amount of oxygen remains constant and the amount of fuel increases with the increasing load. Theoretically, for conversion of fuel into fully oxidized products there should be stoichiometric ratios of fuel and air, which depends on fuel composition [54]. When the engine is fueled with oxygenated blends the surplus oxygen come into view and fuel-lean combustion arise soon after fuel injection. Hence it supports clean and complete combustion and minimizing the emission of CO in the exhaust. A higher A/F ratio of B5b blends (3.1%) proves beneficial as the fuel is to be premixed with sufficient air to form an ignitable mixture during the fuel injection stage. a reduction of 10.7% showed during medium load condition blends B5b which may be due to the cause of this load (controlled combustion phase), rates of burning for naturally aspirated engines are less, therefore challenging higher fuel consumption for similar power generation as diesel.

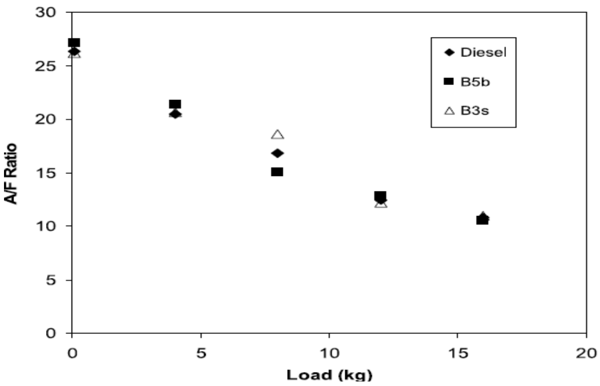

Figure 2. A/F ratio Vs Load

Unmodified engines generally show reductions in power when comparisons of engine performance between ethanol-diesel blends and pure diesel that are approximately the same as the reductions in energy content of the blends relative to diesel fuel.

3.2 Emissions

the exhaust emissions of a DI diesel engine when using 10, 20, 30% ethanol-blended diesel fuels was investigated that according to their experimental results increase ethanol ratio in the blend caused a reduce in CO and HC emissions and an increase in BSFC and NOx emissions. It was also investigated minimum exhaust emissions were obtained in 10% ethanol–diesel blend [55].

Effects of emissions the on CI engine is shown in Figures 3. Figure 3 shows the emission results of the 2-EHN added fuel. At different engine loads the emissions from pure diesel in comparison with E10, adoption of 2-EHN is found able to decrease the HC and smoke. The improvement of NO_x and CO emission depends on the adding percentage of the CI as well as the engine loads [56].

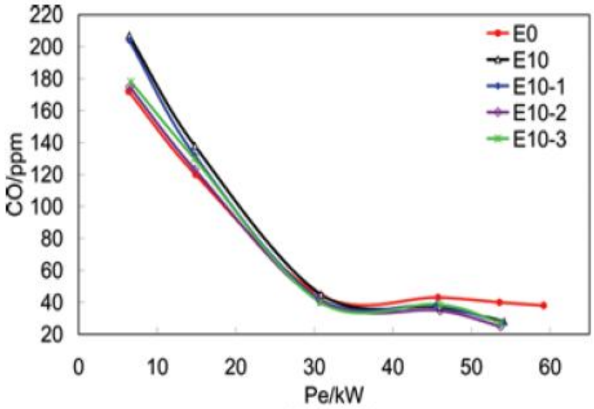

Figure 3 (a) CO emission

Figure 3(b) shows NO_x emission under the light and moderate load conditions when 2-EHN is used the NO_x emission declines but rises up after the moderate load condition. After the 2-EHN addition in the fuel the ignition delay is reduced this is accompanied by a reduction of the heat release rate during the rapid combustion period. The evaporation of the fuel helps to minimize the temperature in-cylinder and leads to lower NOx emission [56].

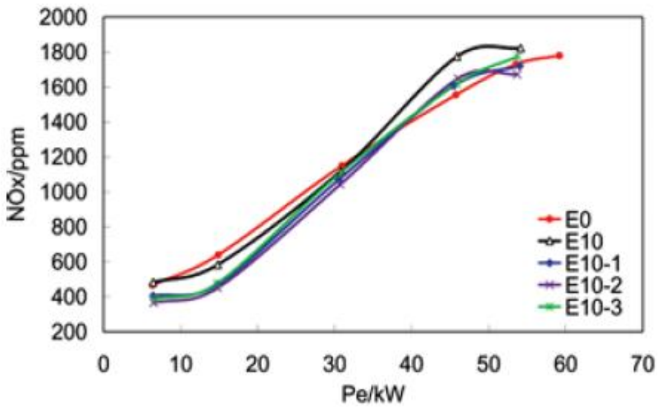

Figure 3 (b). NOx Emission

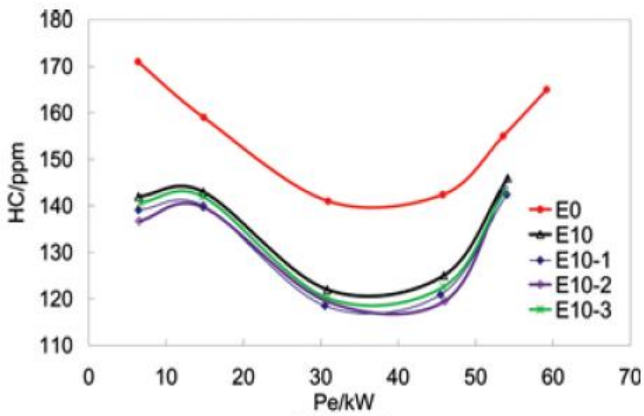

Figure 3 (c). HC Emission

Figure 3. Emissions with addition of 2-EHN at 1700.

The author showed when using 10% and 15% ethanol blends the consistent reduction in PM of 20–

27% and 30–41% respectively. Reductions in NOx varied from zero to 4–5%. Both decreases and increases in CO emissions occurred while THC increased substantially, but both were still well below the regulated emissions limit [51, 57]. It was concluded that from their tests ethanol–diesel blends could be suitable as low emission fuels for current and older model vehicles that are not required to meet future EPA emission standards [51]. However, extensive testing of these fuel types in older and late model diesel engines, need to be performed in order to accurately assess performance.

4. Engine durability

A restricted series of engine durability tests have been performed on ethanol–diesel blends both in the field and in the laboratory. In early on studies, tests using with blends containing 10% and 15% dry ethanol indicated no abnormal wear in engines correctly adjusted for injection timing [58-60]. During these tests some engines were more sensitive to lowering of the cetane number and consequently an improved ignition delay causing piston erosion due to severe localized temperatures and pressures. However, a small retardation of injection timing was recommended so as to reduce rates of pressure rise. During the engine durability tests using blend containing 30% dry ethanol found no abnormal deterioration of the fuel injection system or in engine, it was identified after 1000 h of operation, a small amounts of octyl nitrate ignition improver and ethyl acetate phase separation inhibitor, and the remainder diesel fuel [61]. The use of ethanol - diesel blend naturally decreases the content of sulfur in the fuel in proportion to the amount added, including any sulfur-free additive. A 20% volumetric reduction in sulfur may be provided, thus significantly reducing SO_2 emissions [62].

5. Conclusions

The ethanol–diesel blends properties have a significant effect on engine performance, durability, safety, and emissions. The addition of 4% ethanol to diesel fuel increases the brake thermal efficiency, brake torque, and brake power while decreasing brake specific fuel consumption [63]. For 3% ethanol-diesel blends the engine performance was similar as diesel fuel. The Properties of ethanol-diesel blends are determined in accordance with ASTM standards. Engine performance characteristics such as BSFC compared to diesel with B5b resulting a drop of 2.7% and blend B3s resulted approximately same as diesel. The A/F ratio compare to diesel at medium loads for the B5b blend was lowers by 10.7%, whereas it increased by 10.4% for the B3s blend in comparison to diesel. It was observed that ethanol-diesel blended fuels at high load conditions have stronger effects on smoke, NOx, acetaldehyde emissions and unburned ethanol emissions. At low loads, the blends have slight effects on smoke reduction. With the utilization of additive and ignition improver, CO, acetaldehyde and unburned emissions can be moderately decreased, and THC emissions are significantly reduced and even are less than those of E0 at low loads. With 10% or less ethanol-diesel blends differences in performance compared to running on diesel fuel Long-term durability tests in a range of engines with different fuel injection system configurations will help to confirm that diesel oxygenated with diesel does not adversely affect engine wear compared to diesel fuel.

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