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# A Review on Possibility to Use Ethanol as a Alternative Fuel in Diesel Engine

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*Abstract* - **Ethanol is an attractive alternative fuel because it is a renewable bio-based resource, thereby providing the potential to reduce particulate emissions in compression–ignition engines. In this review the properties and specifications of ethanol blended with diesel fuel are discussed. Special emphasis is placed on the factors critical to the potential commercial use of these blends. The effect of the fuel on engine performance, durability and emissions is also considered. The formulation of additives to correct certain key properties and maintain blend stability is suggested as a critical factor in ensuring fuel compatibility with engines. However, the addition of ethanol to diesel fuel simultaneously decreases cetane number, high heating value, aromatics fractions and kinematic viscosity of ethanol blended diesel fuels and changes distillation temperatures. Also for maintaining vehicle safety with these blends may entail fuel tank modifications. Further work is required in specifying acceptable fuel characteristics, confirming the long-term effects on engine durability, and ensuring safety in handling and storing ethanol–diesel blends.**
*Keywords:* **Ethanol, Ethanol, Blend, Biofuel, Diesel engines.**

## I.INTRODUCTION

Increasing worldwide concern over combustion-related pollutants, such as particulate matter (PM), oxides of nitrogen ($NO_x$), carbon monoxide (CO), total hydrocarbon (THC), acid rain, photochemical smog and depletion of the ozone layer, has led regulatory agencies to implement stringent emission regulations. Diesel engines are one of the major contributors to the pollutant emissions since they are widely used due to high combustion efficiency, reliability, adaptability and cost effectiveness. Soot and $NO_x$ are formed during diesel combustion, the required levels of PM, $NO_x$ are difficult to achieve through the improvement of combus-tion chamber and injection design. It is commonly accepted that clean combustion of diesel engines can be fulfilled only if engine development is coupled with diesel fuel reformulation. In the name of energy security, regional air quality, greenhouse gas emission reduction and even economic savings, oxygenated fuels were advocated to reduce particulate emissions [5]. The reduction of particulate emissions due to the introduction of oxygenated compounds depends on the molecular structure, oxygen content of the fuel [8] and local oxygen concentration in the fuel plume [13].

The engine performance can be studied by various parameters like torque, input power, output power, brake specific fuel consumption, brake thermal efficiency and exhaust gas temperature. Input power is the power produced by the amount of fuel injected to the engine. It is calculated based on the flow-rate and lower calorific value of the fuel. Actually, the input power can be influenced by the level of combustion whether it is complete or incomplete. Of course, it is almost impossible to get the complete combustion in an IC engine [1, 7]. But the more complete combustion, the more input power can be obtained. The calculated input power is the theoretical value and the maximum possible power can be obtained from the fuel if it is burned completely. There will be unburned fuel at every stroke as a result of incomplete combustion. According to a hypothesis, it is good for the cycle. Once the misfire occurred, a small amount of unburned ethanol and air trapped in the clearance volume at the end of the exhaust stroke. This would become diluted during the following induction stroke, resulting in a very lean ethanol-air mixture existing during the following compression stroke. At the end of compression just prior to the next fuel injection, there would be present in the cylinder a small percentage of fully vaporized ethanol at an elevated temperature [10].

## II.PHYSICAL PROPERTIES OF DIESEL AND ETHANOL

The ethanol are fuels of the family of the OXYGENATES. As is known to all, the ethanol molecule has one or more oxygen, which contributes to the combustion. Theoretically, any of the organic molecules of the ethanol family can be used as a fuel. The list is somehow more extensive; however, only two of the ethanol is technically and economically suitable as fuels for internal combustion engines [24-29]. This ethanol is those of the simplest molecular structure. The fuel properties of ethanol and diesel are shown in Table I.

TABLE I FUEL PROPERTIS OF ETHANOL AND DIESEL

| Item | Diesel | Ethanol |
|---|---|---|
| Formula | C12.35H21.76 | $C_2H_5OH$ |
| Molecular weight | 170 | 46.07 |
| Carbon/Hydrogen (W) | 6.76 | 4.0 |
| % Carbon (W) | 87.13 | 52.17 |
| % Hydrogen (W) | 12.88 | 13.4 |
| % Oxygen (W) | 0 | 34.78 |
| Boiling point @ 1 atm °C | 170-340 | 78.40 |
| Freezing point @ 1 atm °C | -40 | -80.00 |
| Density (Kg/m$^3$) | 837 | 789 |
| Viscosity @ 20°C/1 atm, Centipoise | >3 (2.8) | 1.20 |
| Specific heat @ 25°C/1 atm BTU/lb | 0.43 | 0.6 |
| Heat of vaporization,@ boiling point/1 atm, BTU/lb | - | 361.0 |
| Heat of vaporization, @ 25°C/1 atm, BTU/lb | 100 | 396 |
| Heat of combustion @ 25°C, BTU/lb<br>Higher heating value (KJ/Kg) | 10800 | 12780 |
| Lower heating value (KJ/Kg) | 42600 | 26795 |
| Stoichiometric, Ib air/lb fuel | 14.45 | 9.0 |
| Flash point temp. °C | 70 | 12.778 |
| Auto-ignition temp. °C | 315 | 422.778 |
| Lower Flammability limits | 1 | 4.3 |
| Higher Flammability limits | 6 | 19.0 |
| Latent heat of vaporization @ 20°C, KJ/Kg | 220 | 921.36 |
| Cetane number | 50 | 8 |
| Octane number | - | 107 |

From Table I. It can be seen that the lower calorific value of the ethanol is approximately 30% lower than that of the diesel.

## III.ETHANOL

This can be produced from biomass such as potatoes, cereals, beets, sugar cane, wood, brewery waste and many other agricultural products and food wastes in the process of fermentation, and is called bio ethanol; it can also be produced from natural gas and crude oil. Ethanol is not considered toxic; it is soluble in water and is biodegradable. It is more flammable than gasoline. Neat ethanol is rarely used as a fuel. Usually it is mixed with gasoline as an oxygenate to meet clean fuel requirements. For many years a 10 per cent ethanol mixture with gasoline, called ‘gasohol’ or E10, has been used in the United States. Bio ethanol (made from sugar cane) is the primary fuel in Brazil. Because ethanol contains approximately 60 per cent of the energy content of gasoline, it takes more ethanol to get the same mileage as a similar gasoline vehicle. With current technology and price structures, ethanol is more expensive than gasoline. Ethanol does not mix well with gasoline and diesel fuel. Ethanol is a low cost oxygenate with high oxygen content (35%) that has been used in ethanol diesel fuel blends. The use of ethanol in diesel fuel can yield significant reduction of particular matter (PM) emissions for motor vehicle. However, there are many technical barriers to the direct use of ethanol in diesel fuel due to the properties of ethanol, including low cetane number of ethanol and poor solubility of ethanol in diesel fuel in cold weather. In fact, diesel engines cannot operate normally on ethanol-diesel blend without special additives. The main properties of ethanol in comparison with diesel are given in Table I.

### *A.Combustion Characteristics Of Ethanol*

There are some important differences in the combustion characteristics of ethanol and hydrocarbons. Ethanol has higher flame speeds and extended flammability limits. Also, ethanol produce a great number of product moles per mole of fuel burnt, therefore, higher pressure are achieved. The ethanol mix in all proportions with water due to the polar nature of OH group. Low volatility is indicated by high boiling point and high flash point. Combustion of ethanol in the presence of air can be initiated by an intensive source of localized energy, such as a flame or a spark and also, the mixture can be ignited by application of energy by means of heat and pressure, such as happens in the compression stroke of a piston engine. The energy of the mixture reaches a level sufficient for ignition to take place after a brief period of delay called ignition delay, or induction time, between the sudden heating of the mixture and the onset of ignition (formation of a flame front which propagates at high speed throughout the whole mixture). The high latent heat of vaporization of ethanol cools the air entering the combustion chamber of the engine, thereby increasing the air density and mass flow. This leads to increased volumetric efficiency and reduced compression temperatures [6, 7]. Together with the low level of combustion temperature, these effects also improve the thermal efficiency by 10%.

The higher flame speed, giving earlier energy release in the power stroke, results in a power increase of 11% at normal conditions and up to 20% at the higher levels of a compression ratio (14:1). Blending ethanol with gasoline at 0.1%, the power rises to about 0.1%. Power continues to rise steadily as the mixture is enriched to an equivalence ratio of about 1:4. Because of the low proportion of carbon in ethanol, soot formation does not occur and therefore ethanol burn with low luminosity and therefore low radiation. In conjunction with lower flame temperature, about 10% less heat is lost to the engine coolant [8]. The lower flame temperature of ethanol results in much lower NOx (Nitrogen Oxides) emissions. The wider flammability limits of ethanol permit smooth engine operation even at very lean mixtures. But aldehyde emissions are noticeably higher. For ethanol, emissions are acetaldehydes. Increasing compression ratio from 9 to 14, aldehyde emissions can be reduced by 50%, to level compared to that for gasoline. An addition of 10% water reduces aldehyde emissions by 40% and NOx by 50%. Addition of 10% water in the ethanol can be tolerated without loss of thermal efficiency [9].

The oxygen content of ethanol depresses the heating value of the fuel in comparison with hydrocarbon fuels. The heat of combustion per unit volume of ethanol is approximately half that of isooctane. However, the stoichiometric fuel-air mass ratios are such big that the quantity of energy content based on unit mass of stoichiometric mixture become comparable with that of hydrocarbons. The high heat of vaporization and constant boiling point make cold starting very difficult with neat ethanol. The problem is not as severe as in case of ethanol blended with gasoline. Ethanol has a constant boiling point of 80 ° C (78.8° C). Gasoline which has a high vapour pressure (therefore highly volatile) can be used for cold start. Gasoline or petrol is a light, volatile mixture of hydrocarbons for use in internal combustion engines and as an organic solvent. The amount of energy released is dependent on the oxidation state of the carbons in the hydrocarbon which is related to the H/C ratio. The more hydrogen per carbon the lower the oxidation state results in more energy that will be released during the oxidation reaction, thus the greater the H/C ratio and better energy release on combustion. Ethanol generally has H/C ratio nearly 3 promotes an improved combustion, and even the blends of ethanol-diesel may have similar effects [4].

### B.*Brake Thermal Efficiency*

Brake thermal efficiency is the percentage ratio of the output and the input. In this testing, the output is set to a certain load and the input can be calculated based on the amount of fuel used and time taken. With decreasing of input power, the efficiency of the engine increases. The engine efficiency is proportional to combustion efficiency. Improving the other factor such as input power, specific fuel consumption and exhaust temperature will lead to increase in brake thermal efficiency [4]. P.C. Jikar et.al have carried out experiments on ethanol diesel blends at different engine speeds and obtained the values of various parameters such as torque, input power, output power, brake thermal efficiency, brake fuel consummation and exhaust gas temperature. They have used four stroke diesel engines with a compression ratio of 15.5:1. Experimental results showed that the output power and torque for diesel fuel is lower compared to ethanol-diesel blended fuel at any ratio, the exhaust temperature for diesel fuel was higher compared to any mixing of the blended fuel, the brake specific fuel consumption for the three mixing ratios was not varying significantly but the lowest was for 30% ethanol and 70% Diesel but specific fuel consumption for diesel fuel was much lower compared to any mixing ratio [13].

### *C.Effect Of Fuel Blends On Brake Specific Fuel Consumption*

M.Al-Hassan et al. investigated the engine performance and exhaust emissions of diesel engine using 5%, 10%, 15% and 20% ethanol-blended diesel fuels. They have used four stroke single cylinder diesel engine. They have observed that the brake specific fuel consumption of the engine fuelled by the blends was higher compared with pure diesel [11].The brake specific fuel consumption variation of the tested fuels at various engine speeds is shown in Figure 1. It is obvious that the BSFC decreases with the increasing of engine speeds up to 1400 rpm, but increases after 1400 rpm. The minimum BSFC lies between the engine speeds of 1200 to 1400 rpm for all fuel tested. In addition, it can be seen that the BSFC of fuel blends are higher than that of diesel fuel, and increases with the increase of ethanol concentration in the blends. This is because the lower heating value of ethanol and biodiesel is lower than that of diesel fuel. Therefore, more fuel is required to obtain the same engine brake power [14]. Results of A.C.Hansen, Ozen Can and CY [12-14]. Lin shows that diesel fuel blended with ethanol up to 10 vol. % can be used to solve the fuel shortage problems, increase the energy conversion efficiency, improve fuel economy and reduce its harmful emissions. Also using ED fuel blends on diesel engine can yield a significant reduction of carbon monoxide and nitrogen oxide and particulate matter emissions. Nevertheless, a major drawback with using ethanol in diesel engines is the limited solubility of ethanol in diesel fuel; therefore, phase separation and water tolerance in ethanol–diesel blend fuel are vital problems [11, 14].

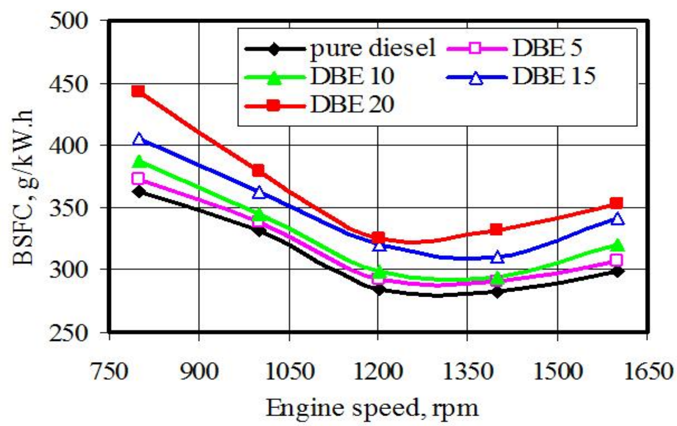


Fig.1 The variation of brake specific fuel consumption [2]

The variation of brake specific fuel consumption with different engine speeds for DBE blends and pure diesel fuel. Huang et al [10] have also investigated the engine Performance and exhaust emissions of diesel engine when using 10%, 20%, 25% and 30% ethanol-blended diesel fuels. In their study, the results showed that the brake thermal efficiencies decreased with increasing amount of ethanol in the blended fuels. Rakopoulos et al. studied the effects of ethanol blends with diesel fuel, with 5% and 10% on the performance and emissions of a turbocharged direct injection diesel engine. The results showed that increasing the ethanol amount in the fuel blend increased the brake specific fuel consumption and decreased the brake thermal efficiency [15]. The phase separation can be prevented in two ways: by adding an emulsifier that acts to suspend small droplets of ethanol within the diesel fuel, or by adding a co- solvent that acts as a bridging agent through molecular compatibility and bonding to produce a homogeneous blend. Emulsification usually requires heating and blending steps to generate the final blend, whereas co solvents allow fuels to be ‘‘splash-blended’’, thus simplifying the blending process [8, 9].

## IV.DISADVANTAGES OF ETHANOL

The disadvantages of the ethanol fuels can be summarized as follows: the economics of production of ethanol may play a role for use as an alternative fuels in Internal Combustion Engine unless the cost of ethanol production from renewable resources is made cost-effective, there will be no demand for it. This ethanol could be produced from biomass, coal, and natural gas. The second disadvantage of ethanol is associated with the flammability, Flame visibility of ethanol is difficult to be detected, which might be hazardous. The lack of visibility is due to the small number of carbon atoms present in the ethanol. Since there is very little carbon, there is no soot formation to give the flame color. Cold stat abilities problem is yet another disadvantage Due to their low vapor pressure, high latent heat of vaporization, and single boiling point, ethanol, especially ethanol, have difficulty meeting industry standards for starting in cold weather. The last two of these disadvantages, however, can easily be solved. By the addition of a small amount of gasoline to the ethanol mixture, a more visible flame will be produced and the effect of cold weather on engine startablity can be brought well within the industry standards. Although this ethanol, when used near their stoichiometric air-fuel ratios, produces more power, a larger quantity of fuel is required to produce a specified power output. For example, in an automobile, more fuel is required for each mile driven [13]. Since the price of ethanol and conventional fuels both fluctuate, miles per rupee should be an important factor in which fuel type or blend percentage to use. Using ethanol or gasoline-ethanol blends generally reduces fuel economy (miles per gallon), but if the ethanol is cheaper, the economics (miles per dollar) may still be favorable. The relatively low boiling points and high vapor pressures of methyl and ethyl ethanol indicate that vapor lock could be a serious problem, particularly at high altitudes on warm summer days. Vapor lock occurs when the liquid fuel changes state to a gas while still in the fuel delivery system. Vapor lock can cause reduce engine power or stalling. Butyl ethanol, because of its low vapor pressure, is the least likely of the ethanol to cause vapor lock. The relatively high latent heats of methyl and ethyl ethanol cause problems in mixing this ethanol with air and transporting them through the intake manifold of the engine. Heating the intake manifold may be necessary in cold weather or before the engine reaches operating temperatures. Without external heat to more completely vaporize the fuel, the engine may be difficult to start and

## V.CONCLUSION

*A.* Ethanol burn more completely than petroleum based fuels thereby increases the combustion efficiency. The mixing of ethanol with gasoline produces gasohol. Similarly ethanol can also be blended with diesel fuels to produce diesohol. Mixing ethanol with gasoline tends to increase the octane rating and reduce carbon monoxide and other tail pipe emissions. The octane number of a fuel indicates its resistance to knock (Abnormal combustion in the cylinder).

*B.* Methyl ethanol has lowest combustion energy and the lowest stoichiometric air fuel ratio. Because of the low stoichiometric air fuel ratio only a small quantity of methyl ethanol mixed with gasoline without affecting the performance. Another advantage of ethanol is that ethanol can also be produced from renewable sources.

*C.* Ethanol has the higher octane rating. This means engine compression ratio can also be increase. An increase in the compression ratio of an engine increases the efficiency of converting the potential combustion energy to power.

*D.* Ethanol is soluble in water, but butyl ethanol is relative in soluble compare to methyl and ethyl ethanol. The engine power is produced low as the water content of ethanol increases. The vapor lock, fuel mixing, and starting problems increase with water.

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