

# Properties of Diesel - Ethanol Blended Fuels with Surfactant

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**Abstract**— In this study, the effect of surfactant on the properties of Diesel-Ethanol blends were investigated. The surfactant is used as an additive for increasing stability of the diesel-ethanol blends. According to hydrophilic – lipophilic balance and the principle of similarity, the emulsification solutions were prepared as per the studies of their properties. It is necessary to add surfactant for keep the stability of the blend. Due to low density and low viscosity of ethanol, the phase separation is occurring at the blend and this can be reduced by blending of emulsification solutions called surfactant. This surfactant increases the blending quality of the Diesel-Ethanol fuels. Although the emission characteristics of blended fuels can be reduced due to oxygenated content in the ethanol fuel. The smoke density and NO<sub>x</sub> emission were reduced as compared to the diesel emission standards.

**Key words** — Diesel, Ethanol, Surfactant – Cetyl Trimethyl Ammonium Bromide and Emulsification Solution.

## I. INTRODUCTION

The depletion of the petroleum resources and increasing transporting vehicle usage was the major cause for alternative fuels. The significance of protecting environment have been promoting the research and developing the alternative fuels for diesel engine to compensate the usage. Ethanol is the reproducible biological resource which is produced from the sugar cane, maize and starch containing vegetables.

Emulsified diesel – ethanol is one of the mix-burning system in which the complete combustion take place. The advantages of emulsification solution are that it can meet the application needs without modifying the diesel engine set up. [1] For Diesel-Ethanol blend fuel the performance and characteristics were found and it resulted in the reduction of NO<sub>x</sub> and smoke emissions. Ethanol was a potential alternative fuels that can be produced from the Mandhuca Indica flower. The ignition delay of the diesel-ethanol emulsions was larger due to inadequate Cetane number of the ethanol fuel. [3] The difficulty of dissolving ethanol in diesel and the stability of the blends is influenced by the temperature and water content. The use of additives that is surfactant improves the solubility of ethanol in diesel and finally it was found that solubility of ethanol in diesel was affected by aromatic hydrocarbons, the temperature of middle distillates. [5] Physical and chemical properties of diesel-ethanol fuel indicate the behavior as compared to neat diesel fuel. Some research result have been proven that the additives can improve not only the stability of ethanol-diesel blends, but their blends can reduce the NO<sub>x</sub> emission by 10% and smoke emission by 15%.lubricity of the

emulsified solution increases with addition of Ethanol fuel. Furthermore, the stability of the blends was more sensitive to water content and additives than the temperature.

[8] Recently, the low temperature combustion mode is an promising method to reduce NO<sub>x</sub> and particulate matter emissions simultaneously. The low temperature combustion (LTC) is achieved with exhaust gas recirculation (EGR) and prolonged ignition delay. Due to lack of miscibility between ethanol and diesel fuels, only a small amount of ethanol was allowed in blends for good results. Low Temperature Combustion (LTC) is favorable for the low Cetane number and increasing volatility of the Ethanol. The surfactant or an emulsifier solution should be used to prevent the separation of ethanol from diesel fuel in that case a biodiesel is used as an additive to stabilize the blend solution. The cetane value of the surfactant solution could compensate for the decrease of cetane number of the blends caused by the presence of ethanol. The main advantages of ethanol blends were to generate low smoke due to the presence of oxygen. The research has been done on the optimum HLB value scale for the emulsification of diesel-ethanol blends. [9] To solve the phase separation in the Diesel-Ethanol emulsions, addition of n-butanol was selected as the additive for the mixing of Diesel-Ethanol and n-butanol solution into emulsification solution fir the complete combustion.

## II. MATERIALS AND METHODS

### A. Production of ethanol

The feedstock used in this study was ethanol which was extracted from the sugarcane, maize grains and starch contained grains. The ethanol source was one of the most available resources from the food crisis. The extraction of ethanol in Fig.1 indicates various processes like milling, fermentation and distillation etc.

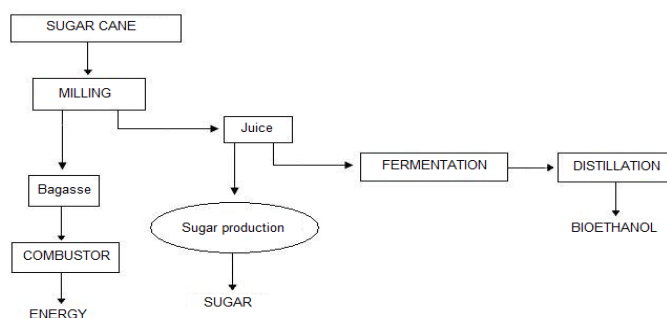


Fig.1. Production of Ethanol

### B. Preparation of emulsifier

Ethanol is immiscible in diesel over the wide range of temperature and water contents due to its properties. The addition of emulsion solution was required to avoid the phase separation and stability of the blends. The water-in-oil emulsion as oil phase and water free ethanol as water phase. According to the theory of “intermiscibility” and “hydrophilic – lipophilic balance” the emulsifying solution were chosen for the diesel - ethanol blends. In order to produce the three – phase emulsion, hydrophilic – lipophilic surfactant must be added. There are many other factors involves in the results of three – phase emulsification were the quantity of surfactants, the HLB value of the surfactants and the oil – to – water intermixture ratio and stirring speed and time for the homogenizing machine.

### C. Properties of fuels

Fuel properties like fuel stability, density, density, viscosity, cloud point, pour point, flash point, fire point, turbidity and water content are tested with the help of ASTM standards. The properties of the diesel and ethanol fuels are listed in the Table 1.

Table 1 Property of Fuels

Properties	Diesel	Ethanol
Density at 15°C	0.823	0.8314
Specific gravity at 15°C	0.810	0.796
Kinematic viscosity at 40°C	4	1.20
Flash point °C	78	13
Cetane number	50	7-9
Calorific value kJ/kg	44600	39450

### D. FUNCTION OF SURFACTANT

The surfactant used in this type of diesel – ethanol blends was cetyltrimethylammonium and it is an amine based cationic quaternary surfactant. As any surfactant, it forms micelles in aqueous solution. At 303 K (30°C) it forms micelles with the aggregation number responsible for the determination of low to high concentration.

The phase separation of the diesel - ethanol blended solution could be avoided by introducing the cetyltrimethyl ammonium bromide solution. With the HLB value of range of 6–9 this shows the better efficiency in the blended fuel performance. The complete combustion of diesel – ethanol blend fuel has been achieved. The property behavior of the surfactant solution that selected was listed below in the Table 2.

Table 2 Behavior of Surfactants

Properties	Value
Melting point	243°C
Boiling point	253°C
Flash point	244°C

## III. RESULT AND DISCUSSION

### A. Fuel Stability

Fuel stability of the blended solution that is diesel-ethanol can be stabilized with the help of surfactant solution which was added to the blend solution. It have been tested by taking each samples in the beaker and kept for longer period of storage. Finally the fuel stability could be found at 25°C ambient temperature of the samples.

### B. Density

Due to low density of Ethanol solution the combustion characteristics like flash point, fire point and calorific value were relatively low when compared to the Diesel. This low density will affect the blended fuel. During the addition of Ethanol fuel to major propulsion shows less specific energy content of the fuel. The Fig.2 shows the density of the fuels blends decreases with the increase in temperature and ethanol quantity simultaneously. This decrease in the density of the blended fuel effect in the injection timing and exhaust pollutants. For all the tested samples density ranges between the ASTM standard values.

### C. LUBRICITY

Lubricity was the property of lubricant behavior that reduces the scar wear of combustion chamber in the diesel engine. In addition of Ethanol to Diesel by proportions the lubricant property were reduced. Some authors presented [5] an improvement in lubricity for high temperature when the Ethanol was added to the Diesel fuel by various proportion in volume basis. These lubricity were tested within the limits of neat diesel fuels as specified in ASTM standards.

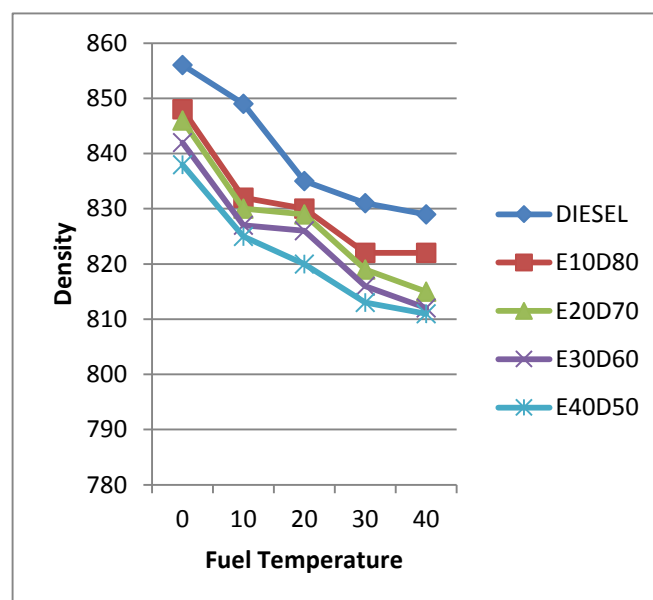


Fig.2. Fuel Temperature Vs Density

**D. Viscosity**

The viscosity of the blended diesel-ethanol fuels were tested with the help saybolt viscometer. For ethanol fuel the average kinematic viscosity is 1.121 mm<sup>2</sup>/s. The Fig.3 shows the viscosities of the diesel and ethanol fuels and it has been proved that the decreasing tendency of viscosity for the addition of ethanol to the diesel fuels. The engine power has been reduced due to the blends viscosity reduced with ethanol addition that leads to deteriorated rate of atomization of fuel in the injection of the diesel engine. Although the tested viscosity values of the blended solutions were lower than the diesel fuel as relative to the ASTM standards.

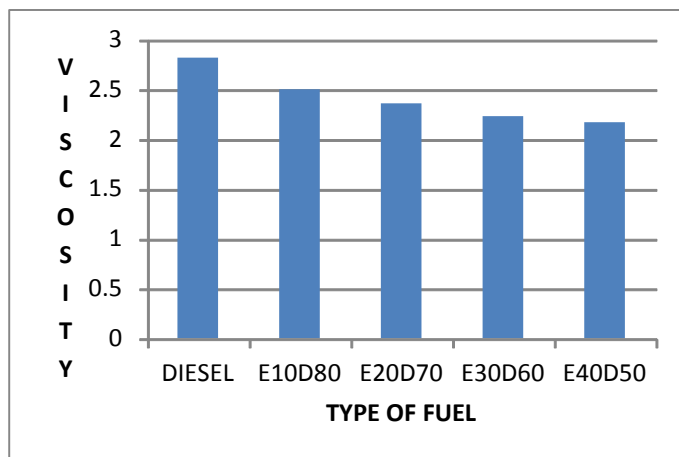


Fig.3 Type of Fuel Vs Kinematic Viscosity

**E. Flash Point**

The flash point of different type if blended fuels have been tested with the Pensky-Martin closed cup apparatus. ASTM standards have been followed when the different blend ratio is tested. The tested result shows the ethanol blended fuels has low flash point when compared to that of diesel fuels. This will leads to the effect in the performance of the diesel engine. Fig.4 shows the tested result of different proportion of the diesel-ethanol fuels.

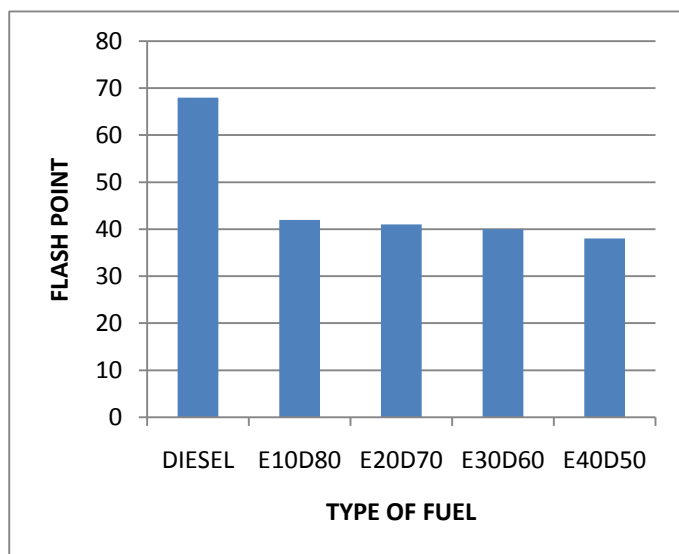


Fig.4. Type of fuel Vs Flash Point

**F. Calorific Value**

For the different proportion of the blended diesel ethanol solution, the calorific value could be determined by the digital Bomb Calorimeter. The various samples of testing solution have been made in the separate beaker and small quantity was taken for the heating of fuel to find the calorific value. Mean while higher heating and lower heating value also determined. It was found to be for the addition of ethanol fuel to the neat diesel will reduce the calorific value of the emulsifying solution.

$$\text{Heat generated} = \text{mass of liquid X Heat capacity of liquid X temperature difference}$$

$$\text{Calorific value} = \text{Heat generated} / \text{mass of fuel used}$$

Table.3 Calorific Value of type of Fuels

Type of Fuel	Calorific Value kJ/kg
DIESEL	45600
E10D80	44520
E20D70	44480
E30D60	44290
E40D50	43900

**G. Water Content**

In the increasing quantity of the ethanol fuels to diesel water content of the blend will increased due to hygroscopic property of the ethanol fuel. The water content of the diesel-ethanol blends solution increased when the quantity of the ethanol is added to the diesel fuel in case of proportions. This quantity of increasing water content in the blends affects the stability and combustion quality which leads to the efficiency of the performance of the diesel engine.

**H. Volatility**

Volatility is the measure of tendency of substance to vaporize the blended diesel-ethanol fuel in the combustion areas. For the diesel-ethanol blend it have been noted that the addition of ethanol to diesel fuel decreasing the tendency of vaporization.

**I. Turbidity**

For the different blend of diesel-ethanol fuels the turbidity value was relatively low for combustion. For blended fuels the turbidity plays a vital role in complete burning of the fuels. This enables the cloudiness or haziness of fluid caused by larger number of individual particles present in the blended solution. The addition of surfactant to the diesel-ethanol emulsions increases the turbidity that will induce the turbulence to the combustion of fuels for complete burning. In this study, the surfactant cetyltrimethylammonium bromide gives closure value of turbidity to the diesel-ethanol blends. Fig.5 shows the water content of the different proportion of diesel-ethanol fuel. These were measured with the help of UV spectrometer according to the ASTM standards.

### J. CHO content

Carbon (C) and Hydrogen (H) content in the diesel fuel was relatively for the combustion but in ethanol these content were not present. Ethanol is an oxygenated fuel, which contains enormous amount of oxygen content. By addition of ethanol to diesel fuel decrease the content of Carbon and Hydrogen in the blend solutions. This gives the beneficial effect of reduced emission rate of the diesel-ethanol fuels.

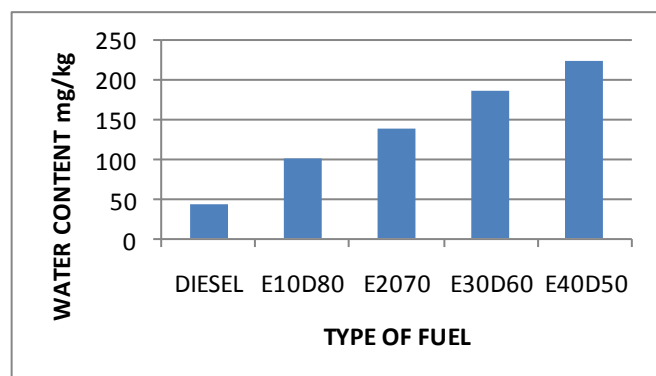


Fig.5. Type of Fuel Vs Water content

### IV. CONCLUSION

- The present work shows the properties of diesel-ethanol-surfactant solutions that provide wide information about the various properties relative to the combustion of the blended fuels.
- Here the property of the tested fuel with different proportion of the blended solutions like Diesel, E10D80, E20D70, E30D60 and E40D50 for each blend 10% of surfactant is added.
- The selection of surfactant solution is based on the “Theory of Similarity” and “Hydrophilic-Lipophilic Balance”. The cetyltrimethylammonium Bromide (surfactant) that added shows the similar results.
- It has been proved that some additives especially like surfactants are needed to keep the stability and phase separation of the diesel-ethanol blend.
- While testing the property of the blend solution, ASTM standard is followed to measure.
- Carbon and Hydrogen content were decreased when the ethanol addition increased. This will leads to lower specific energy content of the different blends of fuel.
- The emission rates are decreased due to introduction of oxygenated fuel like ethanol.
- Turbidity of diesel-ethanol-surfactant solutions were increased due to the property of cetyltrimethylammonium Bromide (cationic surfactant) acts like a detergent which reduces the surface tension between two layer of diesel-ethanol blends.
- The greater the viscosity of the emulsion that is blended solution increases the combustion property.

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