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FUTURISTIC FUEL FOR SUSTAINABLE ENERGY

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ABSTRACT: Environmental concerns and limited amount of petroleum fuels have caused interests in the development of alternative fuels for internal combustion (IC) engines. As an alternative, biodegradable and renewable fuel, ethanol is receiving increasing attention. Various experiments in fermentation process is conducted. The variation of ethanol production adding urea and DAP in fermentation camber is observed. An experimental investigation on the application of the blends of ethanol with diesel to a diesel engine was carried out. The experiments were conducted on a water-cooled single-cylinder Direct Injection (DI) diesel engine using 0% (neat diesel fuel), 10% (E10-D), 15 %(E15–D) and 20% (E20–D) ethanol–diesel blended fuels. Experimental tests were carried out to study the performance of the engine fuelled with the blends compared with those fuelled by diesel. The test results show that it is feasible and applicable for the blends with diesel to replace pure diesel as the fuel for diesel engine.

In 2008 India imported 128.15 million metric tons of crude, instituting 75% of its total petroleum consumption for that year. By 2025 it will be importing 90% of its petroleum (UNESCAP 2009). In an effort to increase its energy security and independence, the Government of India in October of 2007 set a 20% ethanol blend target for gasoline fuel to be met by 2017. The main objective of this project is to develop an economic framework to determine the implications of blend for economic progress and utilize the sustainable energy sources in optimum.

Keywords: Ethanol, Urea, DAP, Fermentation, Blending, Sustainable energy

I. INTRODUCTION

Increased interest on alternative fuels has been observed in the past few years, as a result of increasing energy demand and fore-casted depletion of fossil resources [1,2]. Global warming and the consequent need to diminish greenhouse gases emissions have encouraged the use of fuels produced from biomass [3], which is the only renewable carbon source that can be efficiently converted into solid, liquid or gaseous fuels[4]. Bio-ethanol is presently themo-stabundant bio-fuel for automobile transportation [5]. It is produced from fermentation of sugars obtained from biomass, either in the form of sucrose, starch or lignocelluloses. Sugarcane is so far the most efficient raw material for bio-ethanol production: the consumption of fossil energy during sugarcane processing is much smaller than that of corn [6]. One of the main by-products generated during sugarcane processing is sugarcane baggasse which is usually boilers for production of steam and electrical energy, providing the energy necessary to fulfill the process requirements.

Ethanol fuel is ethyl alcohol, the same type of alcohol found in alcoholic beverages. It is most often used as a motor fuel, mainly as a bio-fuel additive for gasoline. Nowadays, cars are able to run using 100% ethanol fuel or a mix of Ethanol and gasoline. It is commonly made from biomass such as corn or sugarcane. Bio-ethanol is a form of quasi-renewable energy that can be produced from agricultural feedstock. There has been considerable debate about how useful bio ethanol is in replacing gasoline. Ethanol is also being used to formulate a blend with a diesel fuel, known as “E-diesel” and as a replacement of leading gasoline in small aircraft.

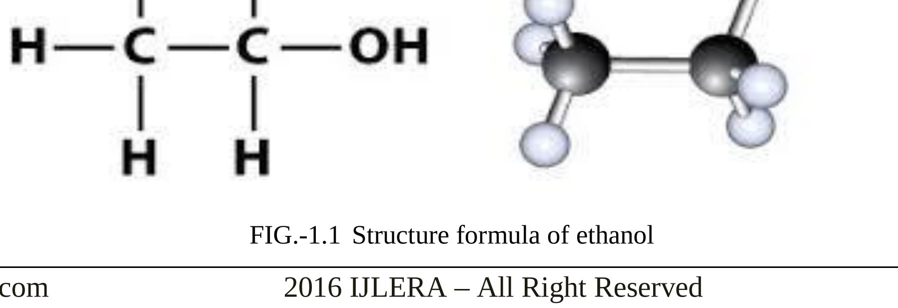

FIG.-1.1 Structure formula of ethanol

1.1 MOTIVATION

Coal, petroleum, natural gas, and other fossil fuels have traditionally been the leading sources of power generation in the world. Interest in finding new sources of fuel has grown in recent years for many reasons, including:

- Environmental Impacts: Combustion of fossil fuels regularly accounts for the majority of the anthropogenic greenhouse gas emissions.
- Waste Generation: Most fossil fuel power plants have low efficiencies; a traditional coal-fired power plant has an efficiency of roughly 32-36%.
- Cost: Finding fossil fuel sources costs money, and this cost could likely increase in the coming years; the Earth has a limited supply of fossil fuels and these fuels will become harder and harder to find.

1.2 OBJECTIVE

- Utilize the sugarcane juice to produced ethanol in domestic and commercial scale.
- To analyze the detail procedure of extraction of ethanol by Fermentation.
- To determine the quantity of ethanol thus produced and study the variation observed after using urea and DAP during fermentation process.
- To test the produced ethanol blended with diesel in a Single Cylinder Four stroke diesel engine.
- To determine the flash point, fire point and calorific value of the produced ethanol.

II. PROCESS & METHODLOGY

2.1 PROCESS

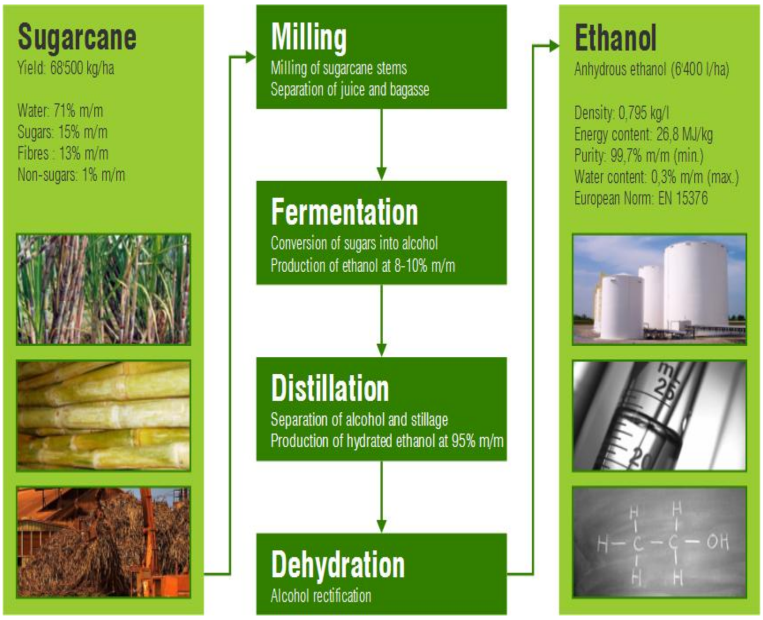

FIG-2.1 PRODUCTION PROCESS

1. Harvesting

The first step is sugarcane harvesting. Much of the harvesting is done with manual labor, particularly in many tropical regions. Some harvesting is done mechanically. The material is then quickly transported by truck to reduce losses. The cane is then cut and milled with water. This produces a juice with 10-15% solids from which the sucrose is extracted. The juice contains undesired organic compounds that could cause what is called sugar inversion (hydrolysis of sugar into fructose and glucose). This leads to the clarification step in order to prevent sugar inversion. In the clarification step, the juice was heated to 115°C and treated with lime and sulphuric acid, which precipitates unwanted inorganics.

Fig 2.1: Harvesting Sugarcane for grinding

2. Grinding and Wet Milling

The cane after harvesting is then cut and milled with water. This produces a juice with 10-15% solids from which the sucrose is extracted. The juice contains undesired organic compounds that could cause what is called sugar inversion (hydrolysis of sugar into fructose and glucose). This leads to the clarification step in order to prevent sugar inversion.

Fig 2.2: Sugarcane grinding

3. Fermentation

The next step for ethanol production is the fermentation step, where juice and molasses are mixed so that a 10-20% sucrose solution is obtained. The fermentation is exothermic; therefore, cooling is needed to keep the reaction under fermentation conditions. Yeast is added along with nutrients (nitrogen and trace elements) to keep yeast growing.

Ethanol fermentation, also called alcoholic fermentation, is a biological process which converts sugars such as glucose, fructose, and sucrose into cellular energy, producing ethanol and carbon dioxide as a side-effect. Because yeasts perform this conversion in the absence of oxygen, alcoholic fermentation is considered an anaerobic process.

The chemical equations below summarize the fermentation of sucrose ($C_{12}H_{22}O_{11}$) into ethanol (C_2H_5OH). Alcoholic fermentation converts one mole of glucose into two moles of ethanol and two moles of carbon dioxide, producing two moles of ATP in the process.

The overall chemical formula for alcoholic fermentation is:

$$C_6H_{12}O_6 \rightarrow 2\ C_2H_5OH + 2\ CO_2$$

Sucrose is a dimer of glucose and fructose molecules. In the first step of alcoholic fermentation, the enzyme invertase cleaves the glycosidic linkage between the glucose and fructose molecules.

INPUTS FOR FIRST TRIAL

- 1500 ml SUGARCANE JUICE
- 200 ml CORN JUICE
- 100 ml POTATO JUICE
- 2 ml SULPHURIC ACID
- 3 gm YEAST

INPUTS FOR THE SECOND TRIAL

- 1500 ml SUGARCANE JUICE
- 200 ml CORN JUICE
- 100 ml POTATO JUICE
- 2 ml SULPHURIC ACID
- 3 gm YEAST
- 2 gm UREA
- 2 gm DAP

4. Distillation

Distillation is a process of separating the component substances from a liquid mixture by selective evaporation and condensation. Distillation may result in essentially complete separation (nearly pure components), or it may be a partial separation that increases the concentration of selected components of the mixture. Distillation means taking the fermented ethanol and water mixture and adding heat to separate them -- typically in a still. Since ethanol evaporates faster than water, the ethanol rises through a tube, collects and condenses into another container. The water is left behind.

After 5 days of fermentation, the sample was filtered using Whatman Filter Paper to separate the ethanol from the residue. The bio ethanol was distilled using rotary evaporator. The sample was heated at 78^0C to get the bio ethanol.

The process of ethanol fuel production involves fermentation, distillation, and dehydration. The general process is shown below. The process begins with photosynthesis, during which plants make sugar which is broken down into ethanol.

$$6CO_2 + 6H_2O + \text{light} \rightarrow C_6H_{12}O_6 + 6O_2 \quad \text{(photosynthesis)}$$

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2 + \text{heat} \quad \text{(fermentation)}$$

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O + \text{heat} \quad \text{(combustion)}$$

Adding these three reactions and balancing, the net reaction simply becomes light → heat. In the first step, ethanol is produced by microbial fermentation of sugars (i.e. starch and cellulose). Currently, only the sugar and starch portions can be economically converted into ethanol. In the next step, distillation, the water is removed from the ethanol. The purity is limited to approximately 95% at this step due to the formation of a low-boiling water-ethanol azeotrope. This azeotrope can be used as fuel on its own, but it is immiscible in gasoline; further distillation is therefore necessary in order for the mixture to burn with gasoline in gasoline engines. This further distillation occurs during the dehydration process, when extra water is removed from the solution.

5. Ethanol extraction

After the fermentation and distillation process finally we extracted the ethanol in the laboratory and then carried out various tests.

6. Ethanol Blending

There are number of fuel properties that are essential for the proper operation of a diesel engine. The addition of ethanol to diesel fuel affects certain key properties with particular reference to blend stability, viscosity and lubricity, energy content and cetane number. Materials compatibility and corrosiveness are also important factors that need to be considered. Ethanol solubility in diesel is affected mainly by two factors, temperature and water content of the blend. At warm ambient temperatures dry ethanol blends readily with diesel fuel. However, below about 10 ^{0}C the two fuels separate, a temperature limit that is easily exceeded in many parts of the world for a large portion of the year. Prevention of this separation can be accomplished in two ways: by adding an emulsifier which 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 (Lutcher, 1983)

The ethanol used in the tests was limited to essentially anhydrous ethanol because other kinds of ethanol are not soluble or have very limited solubility in the vast majority of diesel fuels. The solubility of ethanol in diesel fuel is dependent on the hydrocarbon composition, wax content and ambient temperature of the diesel fuel. This solubility is also dependent on the water content of the blend fuels. To overcome this problem, a solubiliseris indispensable in ethanol–diesel blended fuel. Commercial diesel fuel and analysis-grade anhydrous ethanol (99.9% purity) was used in this test. The compound of ethanol–diesel blends involves solubilizer dosage, ethanol, and diesel fuel. The blending protocol was to first mix the solubilizer (1.5% v/v for all ethanol–diesel blends except for pure diesel fuel) with ethanol, and then blend this mixture into the diesel fuel. For example, 15% ethanol–diesel blends (E15–D) consistsof1.5%solubilizer, 15% ethanol make it difficult to mix with diesel. To overcome that problem the blends two mixed with the additive of ethanol, and 83.5% diesel. The presence of ethanol generates different physic -chemical modifications of the diesel fuel, notably reductions of cetane number, low heat content, viscosity, flashpoint spray characteristics, combustion performance, and engine emissions.

III. TESTS AND ANALYSIS

Engine Specification

SN	Model	Single Cylinder 4-Stroke Diesel Water cooled Engine
1.	Brake Power	3.7 KW
2.	Speed	1500 rpm
3.	S.F.C	251 gm/ kwhr
4.	Lubricant Oil	SAE 30/40
5.	Type	VCR

4.1 Flash Point and Fire Point
Specifications

- Configuration ABA 4 (air-cooled)
- Application range (°C/°F selectable) 10 °C to 110 °C
- Ignition Gas and electric (interchangeable)
- Gas supply 50 mbar of propane or butane

4.2 Viscosity
Specifications

- Dimensions of orifice Length-10mm, Dia- 1,62mm
- Oil Cup Material- Silver plated brass

4.3 Calorific Value
Specifications

- Measurement units: J/kg, cal/gm, BTU/lb
- Temperature resolution: 0.0001°C or better
- Combustion Bomb: Halogen and acid resistant

Comparison of Case Studies

Table 4.1 Comparison of result of case study

Case	Result
1	250 ml ethanol
2	270 ml ethanol

Two case studies had been conducted. In first case study the fermentation was carried out without urea and DAP. In second case study the fermentation was carried out by adding the urea and DAP.

The result of case study shows that the percentage of ethanol was increased by 8%.

Ethanol properties

Table 4.2 Performance test results

SN	Properties	Result
1.	Viscosity	0.0012 Ns/m^2
2.	Flash Point	40^0C at room temperature
3.	Fire point	45^0C at room temperature
4.	Calorific value	34000kJ/kg

The various performance characteristic of ethanol is tested. The viscosity of ethanol was found to be $0.0012Ns/m^2$. The Flash point and was 40^0C and 45^0C at room temperature respectively. The calorific value was 34000kJ/kg.

Observation and Calculation of performance test

Maximum load on the engine:
Brake Power = (2 x Π xNxT)/60
5 x 0.736 = (2 x Π x1550xT)/60
T = 3.33KW
Fuel consumption:
Time for 10 ml fuel consumption = 80

Density of fuel = 820kg/m^3
Calorific value = 44800 kj/kg.
m_f=(pipette reading xρx60)/(Tx1000)
m_f=(10 x 0.82 x 60)/(3.33x1000)
m_f=0.015kg/min
Total fuel consumption (TFC):
TFC = m_f x 60
= 0.015 x 60
= 0.90 in Kg/hr.
Brake specific fuel consumption (BSFC):
B.S.F.C. = (T.F.C.)/B.P
= (0.9/3.68)
= 0.244 Kg/KW – hr.
Brake Thermal efficiency:
$\square_{bth}$ =(B.P. x 3600)/(T.F.C. x C.V)
=(1.73 x 3600)/(0.060 x 44800)
= 23.7%
Mechanical efficiency:
$\square_{mech}$ =(B.P. x 100)/I.P
= (0.92 x100)/1.82
= 50.4%

Table: The table shows the value of E10 (10%ETHANOL, 90%DIESEL)

Torque (NM)	Fuel consumption (Kg/h)	Brake power (k w)	Brake SFC (Kg/ KW-h)	Brake thermal efficiency (%)	Mechanical efficiency (%)	Exhaust temperature (°c)	HC (ppm)	CO (ppm)
0	0.3831	0	0	0	0	109	35	0.492
5.61	0.4789	0.92	0.5205	16.8	50.6	127	32	0.422
10.65	0.6237	1.73	0.3605	24.32	67.25	144	32	0.352
16.61	0.7545	2.67	0.2790	31.4	75.49	164	25	0.363
20.92	0.865	3.33	0.2598	33.7	80.08	184	28	0.520

Table : The table shows the value of E15 (15%ETHANOL, 85%DIESEL)

Torque (NM)	Fuel consumption (Kg/h)	Brake power (k w)	Brake SFC (Kg/ KW-h)	Brake thermal efficiency (%)	Mechanical efficiency (%)	Exhaust temerature (°c)	HC (ppm)	CO (ppm)
0	0.4519	0	0	0	0	112	45	0.582
5.61	0.6386	0.92	0.6509	30	46.8	127	42	0.461
10.65	0.7344	1.87	0.4202	21	63.77	143	39	0.386
16.61	0.8901	2.6	0.3633	26.7	72.52	160	37	0.363
20.92	0.9792	3.3	0.3293	33.42	77.513	178	35	0.523

Table: The table shows the value of E20 (20%ETHANOL, 80%DIESEL)

Torque (NM)	Fuel consumption (Kg/h)	Brake power (k w)	Brake SFC (Kg/ Kw-h)	Brake thermal efficiency (%)	Mechanical efficiency (%)	Exhaust temperature (°c)	HC (ppm)	CO (ppm)
0	0.4602	0	0	0	0	109	48	0.412
5.61	0.6555	0.99	0.6509	13.98	44.5	125	45	0.329
10.65	0.7858	1.87	0.4202	40.5	61.64	143	43	0.246
16.61	0.9476	2.6	0.3633	25	70.68	155	38	0.363
20.92	1.074	3.261	0.3293	27.6	75.88	180	55	0.523

Analysis of Performance of Tests

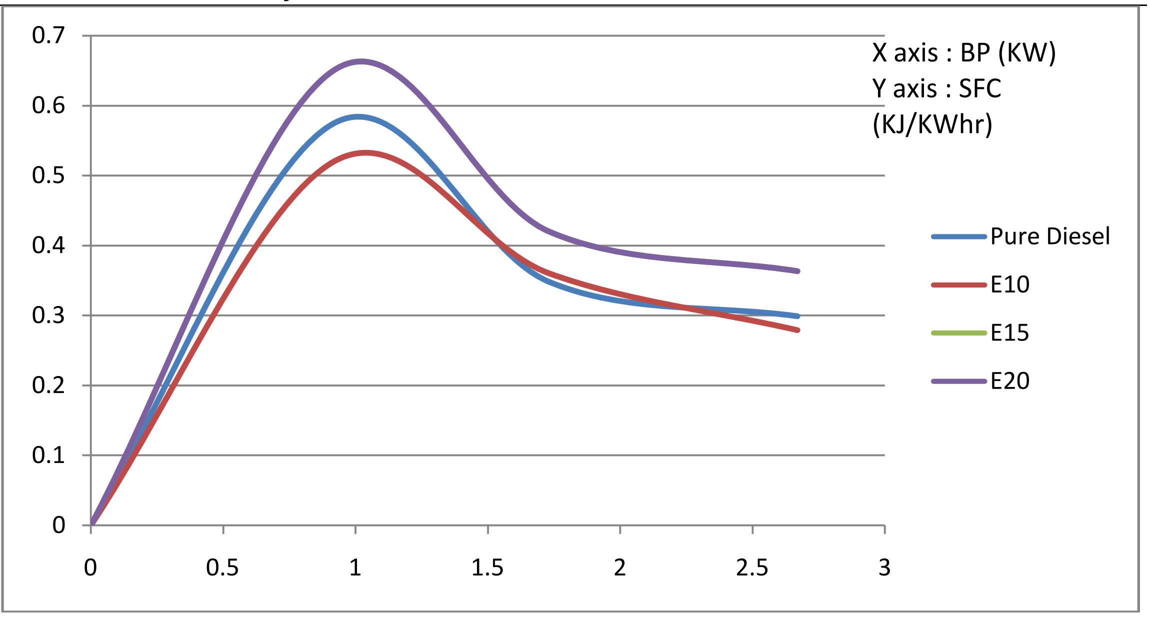

Fig 4.1: Brake Power versus Specific Fuel Consumption

The Brake Power remains constant since the speed and torque is not varied. The Specific Fuel Consumption increases with the increase with the increase in percentage of fuel blends. The efficiency increases until certain point then it decreases with the increase of Brake power. Eg. The E10 has peak fuel com 0.53.

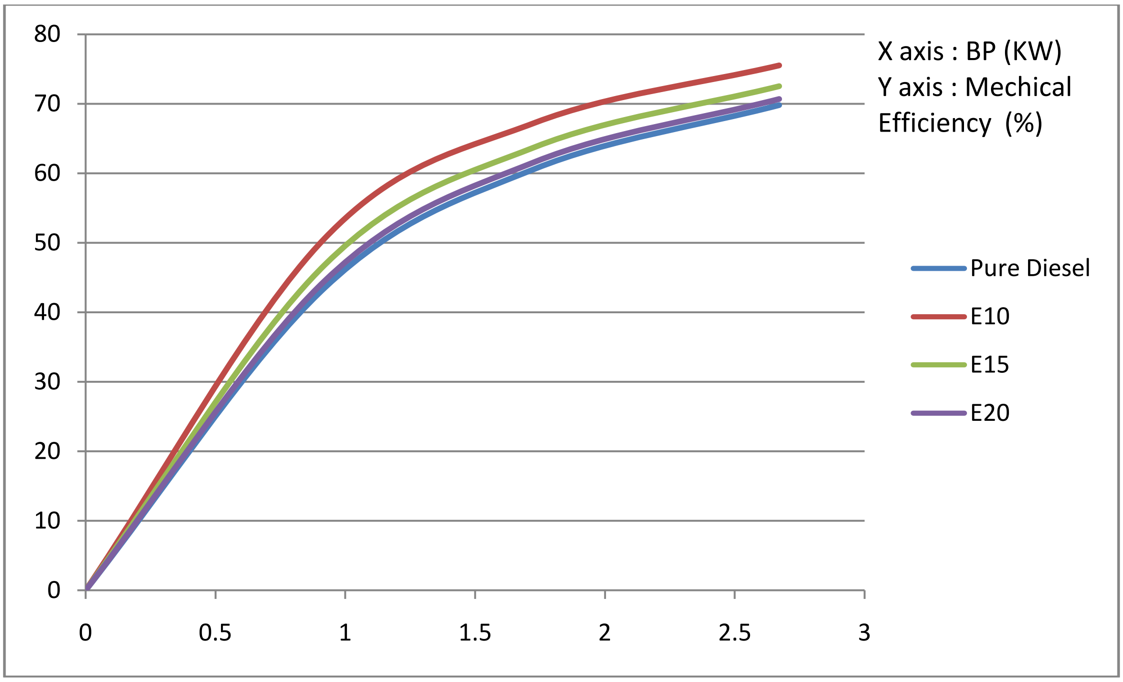

Fig 4.2: Brake Power versus Mechanical Efficiency

The Brake Power remains constant since the speed and torque is not varied. The mechanical efficiency increases with the increase with the increase in percentage of fuel blends.

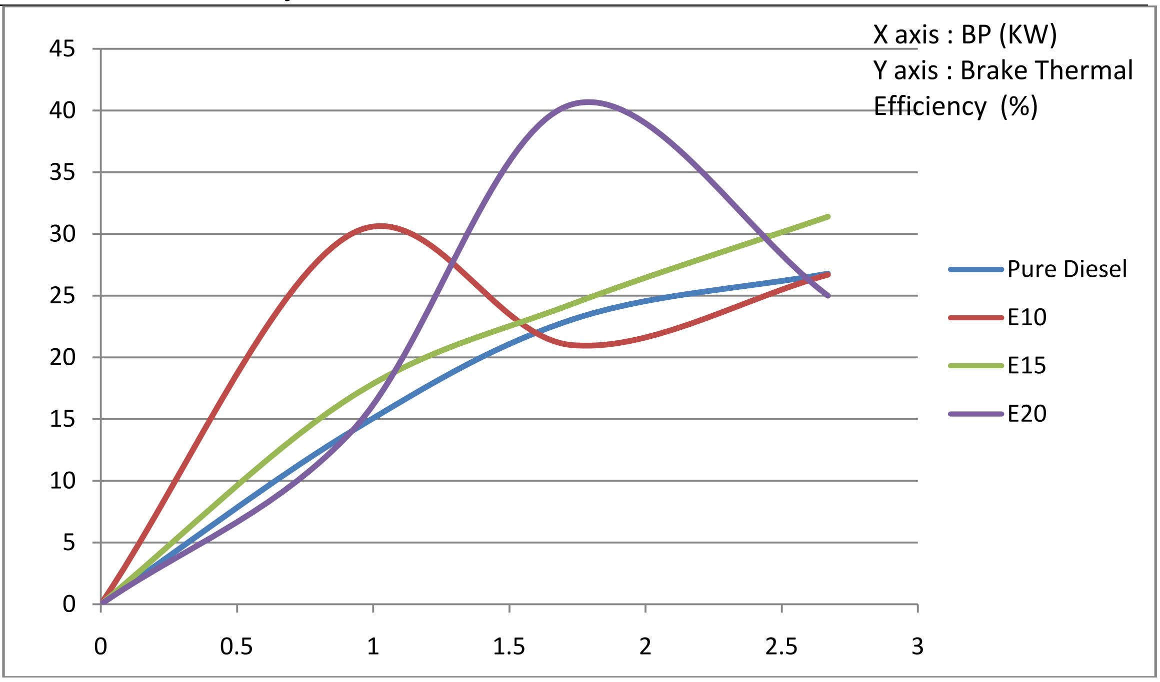

Fig 4.3: Brake Power versus Brake Thermal Efficiency

The Brake Power remains constant since the speed and torque is not varied. The brake thermal efficiency increases with the increase with the increase in percentage of fuel blends. The efficiency increases until certain point then it decreases with the increase of Brake power.

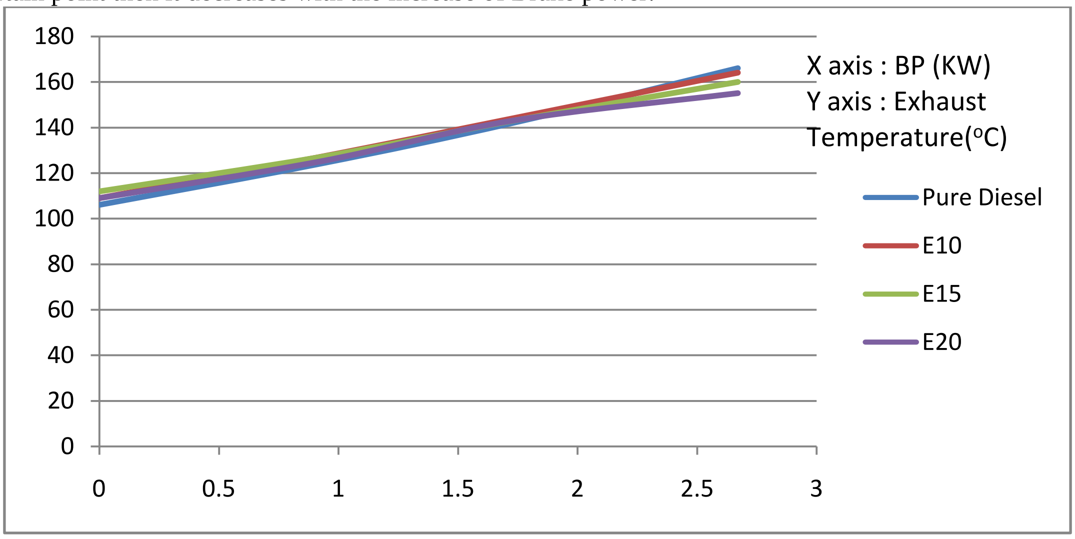

Fig 4.4: Brake Power versus Exhaust Temperature

The Brake Power remains constant since the speed and torque is not varied. The Exhaust temperature decreases with the increase with the increase in percentage of fuel blends.

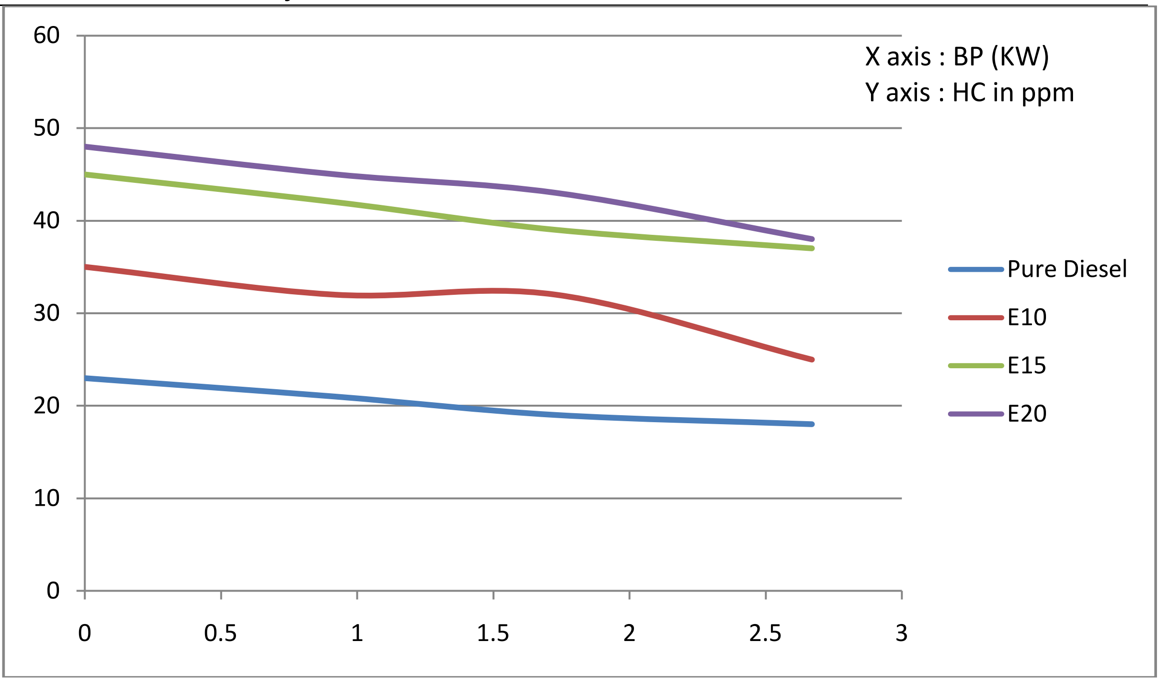

Fig Brake power versus HC emission

The results showed that the HC emissions from the engine for the blend fuels were all higher when the engine ran on the speed of 1500 r/min. The HC emissions for all blends were lower than that fuelled by diesel, i.e. from 4.2% for the blend ofE20D80 to 33.3% for the blend of E15D75.This is due to the high temperature in the engine cylinder to make the fuel be easier to react with oxygen when the engine ran on the top load and high speed.

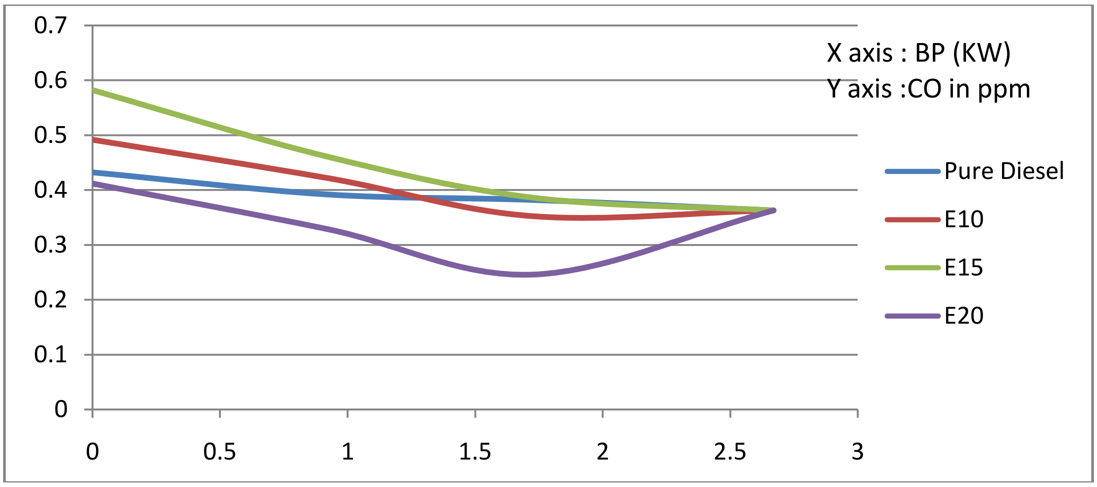

Fig: Brake power versus CO emission

The CO emissions from the engine fuelled by the blends were higher than those fuelled by pure diesel .The higher percentages of the ethanol were more CO emissions happened. But at the engine higher loads which were above half of the engine load, the CO emissions became lower than that fuelled by diesel for all the blend fuels. The carbon monoxide (CO) emissions from the engine. The CO emissions from the engine at the speeds of 1500 when fuelled by different Blends When the engine run at 1500 rpm and at lower loads, the CO emissions from the engine fuelled by the blends were higher than those fuelled by pure diesel.

Economic Viability in context of India

Sugarcane production in India

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Fig 5.1 Sugarcane production in India

Cost Analysis of Ethanol Production in India

Table 5.1 Cost Analysis of Ethanol Production

	Quantity	Rate Rs/L	Cost Rs/L
Molasses cost(5kg)			15.22
Steam kg	3.1	0.5	1.55
Power kwh	0.15	4.5	0.68
Chemicals litres	0.002	128	0.26
Labour			0.25
Repair and Maintaince		0.05	0.67
Manufacuturing overheads		0.1	1.91
Depreciation		0.1	1.33
Administrative Overheads		0.05	1.12
Total cost of Production			24.92
Selling and Distribution overheads		0.05	1.27
Total			26.19

Source: All India Distillers Association (personal communication 2009)

5.2 Current Situation and Future Plan

In 2008 India imported 128.15 million metric tons of crude, constituting 75% of its total petroleum consumption for that year. By 2025 it will be importing 90% of its petroleum (UNESCAP 2009).In an effort to increase its energy security and independence, the Government of India in October of 2007 set a 20% ethanol blend target for gasoline fuel to be met by 2017. In India, the vast majority of ethanol is produced from sugarcane molasses, a by-product of sugar. In the future it may also be produced directly from sugarcane juice. The main objective of this project is to develop an economic framework to determine the implications of the 2017 blend mandate for India’s food and energy security and allocation of land and water between food and fuel production. This is accomplished through the development of a static, spatial, multi-market economic model. The model is a partial equilibrium model which includes eight markets for agricultural commodities: wheat, rice, sorghum, corn, groundnut, rapeseed, cotton, and soybean in addition to the markets for sugar, alcohol and fuel (gasoline and biofuel).

If the Government of India hopes to successfully reach their ethanol blend goal for 2017 with minimum negative side effects on the rest of its economy, my model results suggest that it will need to convert its ethanol industry from one dependent solely on sugarcane molasses to one based primarily on sugarcane juice. My results also suggest that negative impacts on the domestic sugar and alcohol industry and agricultural markets are unavoidable. However these impacts can be lessened through investment in crop production technology and agricultural infrastructure to improve yields and efficiency of irrigation systems to increase availability of water or reduce water requirements for irrigated crop production.

Conclusion

The effects of addition of ethanol in to diesel fuel on the engine performance and emission characteristics of the four cylinder light duty diesel engine have been investigated and compared to the baseline diesel fuel. The main results can be obtained as follow.

a) Ethanol-diesel blends have almost viscosity as diesel and good phase stability.

b) The BSFC is slightly increased due to the lower energy content of ethanol and the brake thermal efficiency is improved with respect to base diesel.

c) The smoke and NO emission is decreased simultaneously when oxygenated diesel blends are used in diesel engines.

d) CO emission and HC emission is slightly increased at lower loads compared with diesel.

e) Blending of renewable fuels with diesel fuel helps to achieve low carbon emissions from diesel engines.

f) After adding urea and DAP during fermentation process the quantity of ethanol was increased by 8%.

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