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IMPACT OF ETHANOL BLENDS ON VARIOUS TECHNICAL PARAMETERS OF A FOUR STROKE 4-CYLINDER IC ENGINE

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Abstract: Due to rapid increasing in population human demands are also increases. So to fulfill all the human requirements various forms of energy should utilizes up to its optimum limit. But our technology is not so advance to utilize whole amount of energy without any loss, which may violates the various laws of physics. Basically for the transport purposes or running vehicle liquid or gaseous fuels are widely chosen due to their high calorific values less storing space and low emissive effects. But there natural stocks are limited so scientists are searching other modes of energy which may compensate these factors and producing cleaner and safer fuel energies.

In India every year two third of fuel energy is utilized for transport purposes for which gasoline or diesel are greatly suited. Due to its availability and wide utility its price is also increasing in an alarming rate. So now a day's other types of liquid fuels which generates from various artificial ways is introduce to work with the conventional fuels for compensating the rate of fuel used and emissive constituents which generates due to the consumption of fossil fuel alone.

In this report we compare Ethanol blends (E10 and E20) with gasoline in a four stroke IC engine and measuring the various parameters by utilizing this mixture.

Key words:- Ethanol, RVP, BHP, CV, HHV, LHV, PON, RON, MON, DIESOHOL

Introduction

Ethanol (C_2H_5OH an alcohol) is the world's largest and fastest growing source of renewable energy with almost all the developing country having some form of bio-fuel industry. Due its clean green image, ease of manufacture and it has an ability to be blended with petrol easily.

Ethanol has been used to power engines for over 100 years, but due to the limitation of gasoline with its emissive effect leads the

growth of production and consumption of Ethanol in different Countries like Brazil, the United States (US) and Europe. At present global ethanol production is over 70 billion liters but as a proportion of total petrol consumption it is still less than 5 per cent. The International Energy Agency[1](IEA) predicts ethanol alone has the potential to make up to 10 per cent of world gasoline use by 2025 and 30 per cent in 2050.

Brazil is the world's largest producer of ethanol driven in part by government policies dating back to the 1970s. Brazil with its low cost feedstock of sugar is able to produce ethanol for less than US\$0.14 cents per liter. The US is the second largest producer and the world's largest consumer of ethanol its industry has also developed as a direct result of government policies, but its production costs are much higher at US\$0.40c/L with corn as its main feedstock.

Now a day government provides various incentives for the production of Ethanol in our country. Though production of Ethanol is quite expensive still lots of research institutes and farms are working in this field for the huge production of Ethanol in India also.

But still we needed advance and cheap techniques by which it may influence our consumption of Ethanol up to its maximum extent.

A. Literature Review :

Various researches which have been done in the past over a time of period came out to be very useful and informative while initiating the above research work.

Poola R.B. Et Al carried out an experiment in the year 1993 with 20% by volume of orange oil and eucalyptus oil were separately

blended with gasoline brake thermal efficiency, exhaust emissions and combustion parameters were obtained. The experiment was conducted on small capacity (145.45 cc displacement volume, 4.3 KW at 5200r.p.m), loop scavenged, air cooled, single cylinder, two stroke -ignition engines with a compression ratio of 7.4. It was found out that the performance fuel blends was better than gasoline fuel. Experiment was performed on two compression ratios viz. 7.4 & 9 and improvement of 20.5% in brake thermal efficiency was obtained at 2 KW, 3000 r.p.m, over the normal gasoline engine. Along with this hydrocarbon and carbon monoxide emission were reduced. While comparing the two fuel blends eucalyptus oil blend provides the best results for brake thermal efficiency with low exhaust emissions.

Tamilvendhan.D Et Al. carried out the experimental study on the performance, emission characteristics of a methyl ester sunflower oil- eucalyptus oil on a single cylinder air cooled and direct injection diesel engine as an alternative fuel and the results which were obtained by the above test were compared with the results while running with standard diesel fuel. When eucalyptus oil having low cetane number is mixed with methyl ester sunflower oil having high cetane number up to 50% results in increase in brake thermal efficiency by 2 to 3 percentage. The

results also indicated the reduction of 37.5% in carbon monoxide emission for the (MeS50Eu50) blend at full load while the hydrocarbon emissions were reduced at both low load and full load but considerably at full load that may be due to the complete combustion of the fuel blend.

M. Senthil Kumar Et Al. (2001) carried out experiment on the use of vegetables directly in compression ignition engines. Along with that Small quantities of orange oil were inducted along with air and ignited after compression. Methyl ester of Jatropha oil and diesel were also used as fuels for comparing the results with that of the vegetable oil.

Purushothaman K. Et Al. (2009) studied about the performance, emission and combustion characteristics of a single cylinder, constant speed, direct injection diesel engine using orange oil as an alternate fuel and the results are compared with the standard diesel fuel operation. The results shows that the brake thermal efficiency is higher than that of diesel operation throughout the load variation.

Devan P K. Et Al. (2009) they worked on to find out the performance, emission and combustion characteristics of a DI diesel engine using poon oil-based fuels and poon oil and poon oil methyl ester are tested in

blended forms They prepared th blend with 20% poon oil and 40% poon oil methyl ester separately with standard diesel. Results obtained show the reduction of CO and HC emissions.

Misra R D Et Al. (2011) , carried out an experiment on a non edible straight vegetable oil blended with diesel in various proportions to evaluate the performance and emission characteristics of a single cylinder direct injection constant speed diesel engine

B. Ethanol :

Ethanol (C_2H_5OH) an alcohol has no of uses including use as a beverage, in industrial applications and as a fuel.

Ethanol can be produced by two ways; synthetically from petroleum or natural gas, or it can be generated from the fermentation of starch and sugars and turned into a Biofuel. On a global scale synthetic feed stocks play a minor role, less than 8 percent of overall output is measured f by synthetic feed stocks.

Synthetic alcohol production is concentrated in the hands of a few mostly multi-national companies such as Sasol, with operations in South Africa and Germany, SADAF of Saudi Arabia, a 50:50 joint venture between Shell of the United Kingdom (UK) and Netherlands, the Saudi Arabian Basic Industries

Corporation, BP of the UK as well as Equistar in the United States (US).

The other 95 percent of Bio fuels are produced from common agricultural plants and from various renewable energy source. Examples include; corn, sugarcane, soybeans, grapes, wheat and waste starch (cellulosic materials). Cellulosic materials, including grasses, trees, and the straw from agricultural grain crops can also be converted to alcohol. While the manufacturing process is more complex and expensive one relative to processing sugars and grains it has the potential to revolutionize the commercial production of ethanol as it will allow a much greater amount of ethanol to be produced from a given land area or biomass volume. This seems to a next generation of fuel technology but the process is only just being proven on commercial scale in a project in few no of countries like Canada and USA.

C. Properties of Ethanol :

One reference [14] (SAE paper 81044, "Emergency Transportation Fuels: Properties and Performance", by Brent Bailey and John Russell) dealt with this issue as part of a larger emergency transportation fuels investigation. Their blend properties for ethanol and a typical gasoline are shown in the corresponding diagrams below.

figure-1: *Effect of Blend on Octane Rating*

figure-2: *Effect of Blend on Lower Heating Values*

Temp (0c)	Density(*1000 Kg/m ³)	Viscosity (Pa-s)	Kinematic viscosity (m ² /s)	Surface Tension (N/m)	Bulk Modulus (GPa)
0	0.806	1.77*10 ⁻³	2.20*10 ⁻⁶	2.41*10 ⁻²	1.02
20	0.789	1.20*10 ⁻³	1.52*10 ⁻⁶	-	0.902
40	0.772	8.34*10 ⁻⁴	1.08*10 ⁻⁶	-	0.789
60	0.754	5.92*10 ⁻⁴	-	-	0.678

Table-1 :Ethanol Properties

NB-All properties are taken at 1atm (1.01325*10⁵Pa) [18]

figure-3: *Effect of Blend on Specific Air Fuel Ratio*

figure-4: *Effect of Blend on Reid Vapor Pressure (RVP)*

figure-5: *Effect of Blend on Specific Gravity*

D. Blends/Grades :

Ethanol can be produced in two forms; Hydrus (or hydrated) and Anhydrous [15].

Hydrus ethanol typically has a purity of about 95 per cent plus 5 per cent water this can be used as a pure form of fuel in specially modified vehicles. Only Brazil produces vehicles that run on this form of ethanol.

Anhydrous alcohol, (water-free or "absolute") is when the last traces of water are removed. Anhydrous ethanol requires a second-stage process to produce high-purity ethanol for

use in petrol blends; in effect, the 95 per cent pure product is dehydrated using Azeotropic processes or a molecular sieve to remove the water, resulting in 99 per cent pure ethanol. Anhydrous ethanol is typically blended with 10 to 25 per cent volume in petrol for use in most unmodified or slightly modified engines. Or as a 3% blend in Diesel.

Ethyl alcohol as an automotive fuel can be used in two ways. Firstly, it replaces gasoline outright in dedicated internal combustion engines and secondly, it is an effective "octane booster" when mixed with gasoline in blends of 5 to 30 per cent. In this case no engine modifications are required. These blends achieve the same octane boosting or anti-knock effect as petroleum derived aromatics like benzene or metallic additives like lead. Ethanol easily blends with gasoline but not with diesel. If the Diesohol blend is to obtain more than 3 per cent ethanol, special emulsifiers are needed. Various ethanol fuels are produced:

- a) E10, 10 per cent ethanol and 90 per cent petrol mix. This is the international standard and can be used in almost all cars.
- b) E85, 85 per cent ethanol and 15 per cent petrol mix used in the US but requires specialized technology known as Flexible Fuel Technology .

- c) E20 -26, 20-26 per cent ethanol Brazil requires vehicle fuel recalibration and new parts.
- d) E100 100 per cent ethanol used in Brazil and requires vehicle specific technology.
- e) D85 E-Diesel or Diesohol is 3-15 per cent ethanol and 97-85 per cent diesel.

E. World Production Rate :

a. Continent Wise

Table 2: world Ethanol Fuel production in (Million Liters) [17]

*Expected values

figure-6: Production of Ethanol in Various Countries

F. World Ethanol Consumption Rate :

figure-7: World Ethanol Consumption Rate

b. Country Wise

Year	Europe	Africa	North and central America	south America	Asia/Specific	Others	TOTAL
2006	1627	0	18716	16969	1940	39252	78504
2007	1882	55	25271	20275	2142	49625	99250
2008	2855	65	35946	24456	2753	66075	132150
2009	3645	100	42141	24275	2972	73088	146221
2010	4254	130	51584	25964	3115	85047	170094
2011	4429	150	54756	21637	3520	84501	168993
2012	4973	235	54580	21335	3965	85088	170176
2013*	5500	350	60000	21550	4500	86075	177975

Properties Of Fuel On Engine Performance

A. Calorific Value

the actual heat energy liberated by the complete combustion of fuel in the presence of oxygen. Experimentally it is proved that gaseous fuels have more calorific values as compared to the solid or liquid fuels. these are mathematically written as (LHV or HHV). HHV is the maximum heat content of a fuel where as LHV is the actual heat content calculated by considering all type of losses taken into consideration. In other words, the heating value indicates how much energy is

contained in a fuel. Increasing the heating value of a fuel will increase the power output of an engine [7]

B. Octane Number

The octane number of a fuel is a measure of the tendency of the air-fuel mixture to resist self-ignition. This pre-ignition, or knock, decreases engine efficiency and increases engine wear [8]. If a fuel has a higher octane number, then it can endure a higher compression ratio before exploding. Although the octane number by itself does not imply better engine performance, engines with higher compression ratios are more powerful and efficient, and they need to run on fuels with high octane numbers [8].

C. Flame Speed

The laminar flame speed represents the speed at which a one-dimensional laminar flame propagates into the unburned gas under adiabatic conditions [6]. This fuel property determines how fast the mass of fuel will be burned in the cylinder. A high flame speed reduces the time required for complete combustion, which produces lower exhaust temperatures, higher engine efficiency, and lower tendency to knock [8].

D. Ignition temperature

For the combustion of any fuel proper ignition temperature is very essential. It is a great

desirable properties of any fuel for complete ignition by which maximum amount of heat energy can evolved.

E. Fuel Constituents

Constituents of fuel plays a great role on heating values and emission simultaneously. Fuels are mainly constituted of carbon as its base composition with Methane, Ethane, Propane for gaseous fuels, sulfur, Nitrogen, oxygen moisture and ash with some portion of volatile components for solid and liquid fuels. more the amount of carbon in solid fuels give higher heating values but simultaneously produces the emission problem. in the same manner more constituents of CH_3, CH_4 can produce higher energy output. But, presence of (NO_x and S) can cause serious health hazard due to higher emissive effects.

Emission From I.C. Engines

A. Carbon Monoxide (CO)

Carbon Monoxide (CO) is a colorless, odorless, poisonous gas created when an engine is operated with a fuel-rich equivalence ratio. Not only is CO an undesirable emission, but it also represents lost chemical energy that was not fully utilized in the engine [7]. CO forms when there is not enough oxygen to convert all the carbon in a fuel to CO_2 [7]. Therefore, the key

to minimizing CO emissions is to reduce the time that the engine needs to run rich, such as start-up, because this is when there is less oxygen available in the cylinder [6]. Ethanol blends, which contain oxygen in its chemical make-up, also decrease CO emissions in comparison with pure gasoline [1, 13].

B. Carbon Dioxide (CO₂)

Carbon Dioxide (CO₂) emitted from combustion engine fuels does not directly threaten human health, but it does contribute to global climate changes [1]. Although CO₂ emissions from gasoline and ethanol blends are nearly equivalent, CO₂ emissions from ethanol can be recaptured by the very plants that are grown to create ethanol [4]. While it is not known if this renewable ethanol cycle would completely nullify the CO₂ emissions from ethanol, it is clear that at least part of the CO₂ emissions would be avoided.

C. Nitrogen Oxide (NO_x)

Nitrogen oxides (NO_x) are mainly created from nitrogen in the air during the combustion process. Nitrogen oxides react in the atmosphere to form ozone and are one of the major causes of photochemical smog. Ground-level ozone harms the lungs and other biological tissues [7]. Some studies have shown that ethanol blends (up to 30%

by volume), when used as a fuel in spark ignition engines, reduce NO_x emissions [8]. Other studies have shown that NO_x emissions from E10 and gasoline are about the same [1].

Experimental Setup

A. Engine Specification

Test Engine Parameters	
Bore	84mm
Stroke	82mm
Capacity	1817CC
Indicated Power	12.674 KW
RPM	5000
BHP	74hp
Fuel Used	Gasoline
CV	44650 Kj/Kg
Compression Ratio	9.8:1
Volume Displace	2.0 L
No of Cylinder	4
Number of Valves	16
Firing Order	1,3,4,2

Table 3: Testing Engine Specification

figure-8: Machine Setup for Ethanol Testing Machine

B. Blend of fuel used

We used the following fuels in the experiment:

- Gasoline (88 octane) purchased from a reputed Fuel filling station
- 100% Ethanol (Denatured Ethyl Alcohol)

Conducting Experiment

We performed the experiment for pure gasoline, a 10% ethanol-gasoline blend, and a 20% ethanol-gasoline blend. *Table 4* summarizes the different settings for each of the 9 different tests performed. In all settings, the following procedure was followed.

Step 1-We created the mixtures by weighing the appropriate amount of ethanol on a scale, and then added it to the gasoline (applied for the ethanol blends only).

Step 2 – We emptied the engine fuel tank and filled it with the fuel to be tested.

Step 3 – We started the engine and let it run at the required fuel flow and engine speed for about 3 minutes in order to allow the engine to stabilize.

Step 4 – We recorded 10 measurements of the fuel flow, engine speed, air flow, dynamometer force, vacuum pressure, and the level of concentration for NO_x, CO, CO₂

Test Readings at different Conditions		
FUEL	FUEL FLOW READING (COUNTS/10 SEC)	ENGINE SPEED (RPM)
Gasoline	100	2700
Gasoline	200	2700
Gasoline	300	2700
10% Ethanol	100	2700
10% Ethanol	200	2700
10% Ethanol	300	2700
20% Ethanol	100	2700
20% Ethanol	200	2700
20% Ethanol	300	2700

and O₂.

Table 4: Test Readings at Different Conditions

Calculation

A. For calculating Load lifted

Gasoline		10% Ethanol		20% Ethanol	
BP(KW)	W(Kg)	BP(KW)	W(Kg)	BP(KW)	W(Kg)
0.2	0.215	0.2	0.215	0.2	0.215
2.32	2.488	2.44	2.616	2.16	2.316
3.33	3.571	3.5	3.753	3.12	3.345
1.95*	2.091*	2.047*	2.194*	1.826*	1.958*

Table5: Load lifted by different grades at specific BP
NB *- Average Values

figure 15: Load lifted verses BP

B. For calculating mechanical efficiency

Gasoline		10% Ethanol		20% Ethanol	
BP(KW)	η_{mech}	BP(KW)	η_{mech}	BP(KW)	η_{mech}
0.2	0.0157	0.2	0.0156	0.2	0.0157
2.32	0.183	2.44	0.193	2.16	0.170
3.33	0.262	3.5	0.276	3.12	0.246
1.95*	0.153*	2.047*	0.161*	1.826*	0.144*

Table 6: Mechanical Efficiency by different grades at specific BP

NB *- Average Values

figure 16: Mechanical Efficiency versus BP

C. For calculating Frictional power

Gasoline		10% Ethanol		20% Ethanol	
BP(KW)	FP(KW)	BP(KW)	FP(KW)	BP(KW)	FP(KW)
0.2	12.474	0.2	12.474	0.2	12.474
2.32	10.354	2.44	10.234	2.16	10.514
3.33	9.344	3.5	9.174	3.12	9.554
1.95*	10.724*	2.047*	10.627*	1.826*	10.847*

Table 6: Frictional Power by different grades at specific BP

NB *- Average Values

figure 17: Frictional Power versus BP

Average values of all tests				
	Break Power (BP), KW	Mechanical Efficiency (η_{mech})	Frictional Power (FP), KW	Load Lifted (W), Kg
Gasoline	1.95	0.153	10.724	2.09
10% Ethanol	2.05	0.161	10.627	2.194
20% Ethanol	1.83	0.141	10.85	1.96

Result Analysis

The variability in the data for the performance parameters was relatively low. To show this, error bars of the uncertainty have been displayed in each of the three charts for fuel performance shown below. The uncertainty for Brake Work is small. More important is the uncertainty in the fuel conversion efficiency, where it seems the uncertainty could cause the results to be different from the averages.

A. From Engine Parameters

1. Effect on Brake Power (B.P.)

figure-9: Effect on Brake Power

Brake work was found to be relatively equal for all three fuels at the 2 lower fuel flow rates as shown in Figure 9. At the highest fuel flow rate, the gasoline has the highest brake work,

followed by the 10% ethanol blend and 20% ethanol blend. This is a direct result of the heating value of the ethanol blends and gasoline. Gasoline has the highest heating value; therefore, gasoline produced the greatest brake work at the widest throttle setting. However, it is difficult to generalize the findings for all 3 fuels, because the lower throttle settings did produce the same results. It is important to note that the 20 ethanol blend produced less work than gasoline at all 3 throttle settings

2. Effect on Brake Specific Fuel Consumption (BSFC)

figure-10: Effect on Brake specific Fuel Consumption

The results for the brake specific fuel consumption of gasoline, 10% ethanol blend, and 20% ethanol blend are shown in *Figure 10*. The BSFC for 20% ethanol blend was always higher than regular gasoline, especially at low throttle. This is another result of the lower heating value of the two fuels. In layman's terms, a gallon of 20% blend in a passenger car would not go as far as a gallon

of regular gasoline. On the other hand, the BSFC for 10% blend was lower at low throttle, the same at middle throttle, and higher at high throttle. Also, it can be seen from the error bars that the BSFC at fuel flows of 200 and 300 counts are nearly identical. Thus no conclusion can be made from the data collected as to a noticeable difference between each fuel at higher throttles

3. Effect on Conversion Efficiency (η)

Figure 11 displays the results for fuel conversion efficiency. The gasoline and 10% ethanol blend are nearly identical in terms of efficiency. This proves that other fuel properties such as the laminar flame speed and heat of vaporization can counteract the energy content in a fuel, as indicated by the heating value, to produce the same fuel conversion efficiency. At the same time, the 20% ethanol blend produced efficiency about 2.5% less than gasoline and 10% ethanol blend at high throttle. In addition, as the throttle is opened wider, fuel conversion efficiency of 20% ethanol increases, but not as much as the other fuels do. The average passenger car engine would need the fuel/air system to be modified to improve the efficiency of a 20% ethanol blend, especially to compensate as the throttle is being opened wider.

figure-11: Effect on Conversion Efficiency

B. From Emission Parameters

1. Emission of CO

figure-12: Effect on CO Emission

Figure 12 displays the Carbon Monoxide emissions for all 3 fuels. Although there is a large amount of variability in the data (see Appendix B), it is safe to say that the gasoline emitted a lot more Carbon Monoxide than either of the ethanol blends. This is due to the fact that CO is formed when there is not enough oxygen for all of the carbon content of fuel to convert to Carbon Dioxide. Ethanol is an oxygenate; therefore, ethanol blends will have more oxygen in their chemical structure than pure gasoline, decreasing the chance that the carbon from the fuel will not be able to form CO₂ during combustion

2. Emission of CO₂

 figure-13: Effect on CO₂ Emission

The uncertainty for the CO₂ emissions was very low in this study. Figure 13 displays the results for the CO₂ emissions. It is clear the highest emissions were produced while operating on 20% ethanol blend. The 10% ethanol blend produced the lowest emissions. All of the results are within 0.5% of each other. It is important to remember that although the Carbon Dioxide emissions were highest for the 20% ethanol blend, a high percentage of the CO₂ emitted by the ethanol blends will be recaptured as more ethanol is produced.

3. Emission of NO_x

The results for the NO_x emissions are displayed in Figure 14. There are very few solid trends present in the data. The NO_x emissions for 20% ethanol on average are smaller than those of pure gasoline. 10% ethanol blend produced the highest NO_x emissions at the lower two fuel flow rates. The only responsible conclusion to be made based on the data is that NO_x emissions are

of a similar order for all 3 fuels, meaning that all the emissions were less than 50 ppm

figure-14: *Effect on NOx Emission*

Conclusion and Discussion

The methods used to obtain these results have a few weaknesses. The same gas tank was used to feed the engine for every test; thus, some residual test fuel may have remained in the tank, diluting the next test fuel. The engine ran smoothly at certain fuel flow rates and engine speeds, while at others the engine speed fluctuated. These bursts in speed may have influenced the results. At the same time, the results agree with current theory, and therefore they are valid findings. Therefore, 10% ethanol blends can be more widely used in the United States without any major emissions or engine performance repercussions. Further research still needs to be done to determine how ethanol blends perform in diesel internal combustion engines that are not modified. Higher percentage ethanol blends also need to be tested in spark

ignition engines. Finally, the true production costs of ethanol need to be established.

1. 10% ethanol-gasoline blends can be used in spark ignition engines without any major modifications to the air/fuel system. The 10% ethanol blend produces similar fuel conversion efficiency, brake work, and BSFC to that of pure gasoline. CO emissions for 10% ethanol blends are much lower than CO emissions from gasoline. NOx and CO₂ emissions for 10% ethanol blends and gasoline are similar.

2. 20% ethanol-gasoline blends do not perform as well as pure gasoline does in spark ignition engines that are calibrated to run on gasoline. The fuel conversion efficiency and brake work both decrease for an engine operating on a 20% ethanol blend, while BSFC increases. CO emissions for 20% ethanol blends are much lower than CO emissions from gasoline. The NOx emissions for 20% ethanol are similar to those of pure gasoline. CO₂ emissions are higher for 20% ethanol blend than for what is produced by gasoline.

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